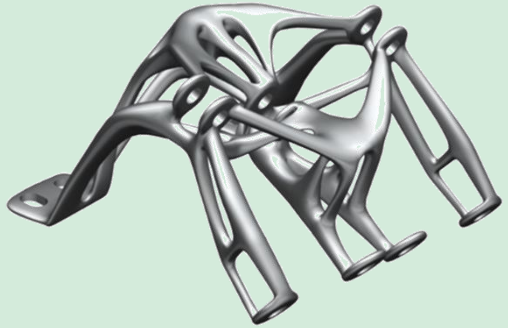
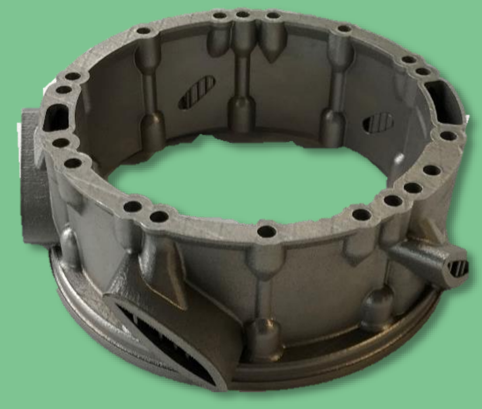
Closure Presentation

www.encompass-am.eu

ENCOMPASS

DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM





PHOTONICS21

FoF

The ENCOMPASS project has received funding by the photonics and Factories of the Future (FoF) Public Private Partnerships (PPP), under grant agreement no. H2020-fof-2016-723833-ENCOMPASS. The project is an initiative of the Photonics and Factories of the Future Public Private Partnership.

CONSORTIUM

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ENCOMPASS CALL

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1st October 2016 → 41 months

H2020-IND-CE-2016-17-FOF-13-2016 call → Rapid individualised laser-based production

Factories of the Future: From "Design to piece" → 4 040 371.25 €

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PROJECT MOTIVATION

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Manufacturing

- 3 trillion € (21%) of the EU's GDP
- 20% of EU's employment ⇒ 30 million jobs in 230 000 enterprises (SME mostly) (Eurostat, 2016)
- EU market share of laser based manufacturing declined (39% in 2008 → 33% in 2012) ⇒ due to competition from Asia (Helmrath, 2015)

AM market

- Threatened by lower wage economies and high tech rivals
- Grew at a GAGR ≈ 35% to 35 bn € ⇒ will grow to over 90 bn € by 2020 if key technological challenges can be overcome (Wohlers Report 2015)
- Industrial machinery and consumer goods account for > 36% of the industries using (AM Valles, 2014)
- Automotive, Aerospace and Medical: focus end-users for ENCOMPASS – 43% of the industries using AM

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OVERALL OBJECTIVES

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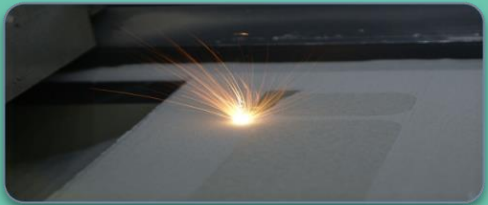

Develop an Integrated Design Decision Support (IDDS) system

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The integration at digital level enables numerous synergies between the steps in the process chain and the steps themselves (design, build and post-build processes) to be optimised

Allow Europe to achieve global leadership in this important field of net-shape AM

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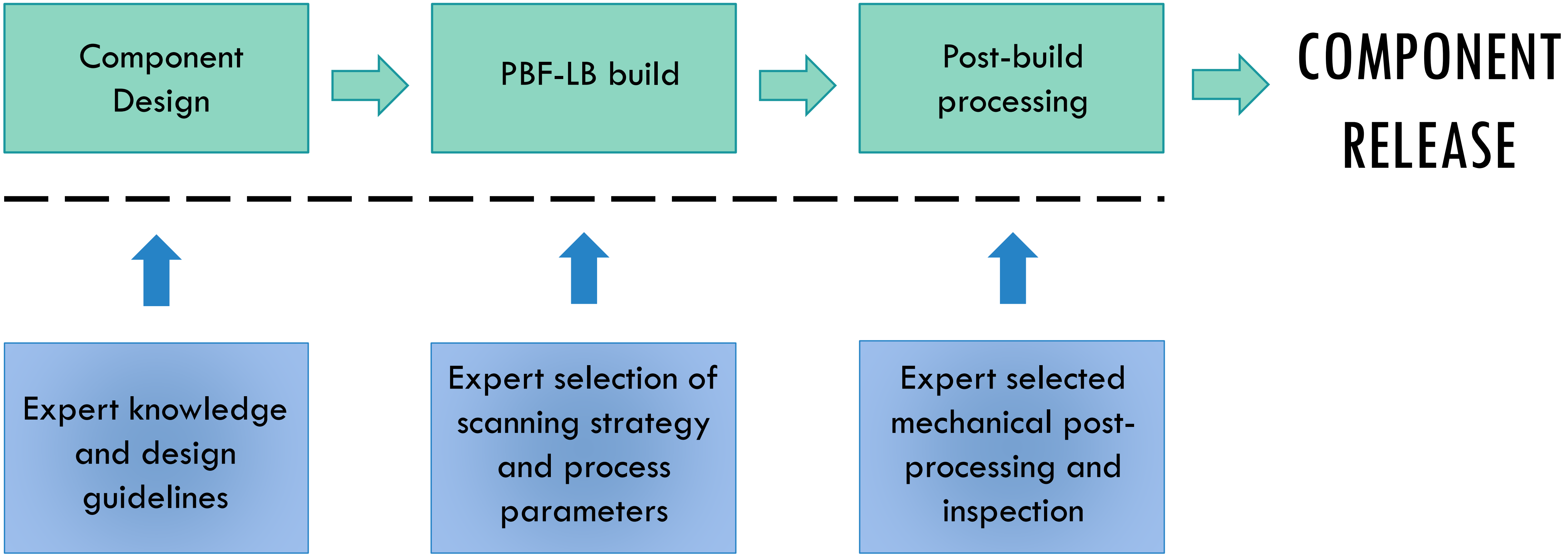
CHALLENGES OF MULTI STEPPED PROCESS



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ENCOMPASS FOCAL POINTS

A user support interface within the CAD environment

Digital tools for simulating and optimising melt strategies

Digital tools for simulating post-build material and quality processes

Apply monitoring solutions for key variables of the post-PBF-LB processes

Develop a framework for optimisation of PBF-LB product and process design

Demonstrate benefit of IDDS for end user driven case studies across the aerospace, medical and automotive sectors.

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THE CONCEPT …

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Integrated Design Decision Support (IDDS) system

Design Process

- ✓ Geometry-specific scanning strategies
- ✓ Targeted feature tracking
- ✓ Design for manufacture

LPBF Building

- ✓ In-process monitoring
- ✓ In-process response
- ✓ Informing downstream

Post-building processes

- ✓ Design for post- processing
- ✓ Design for inspection
- ✓ Targeted feature post-processing/inspection

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IDDS SYSTEM

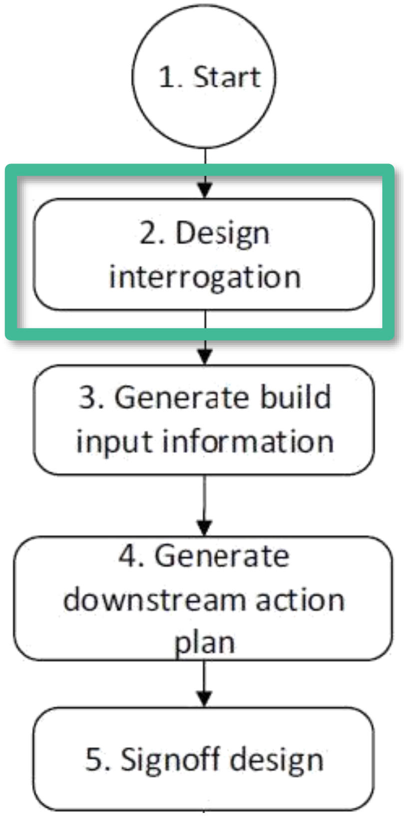
Success criteria:

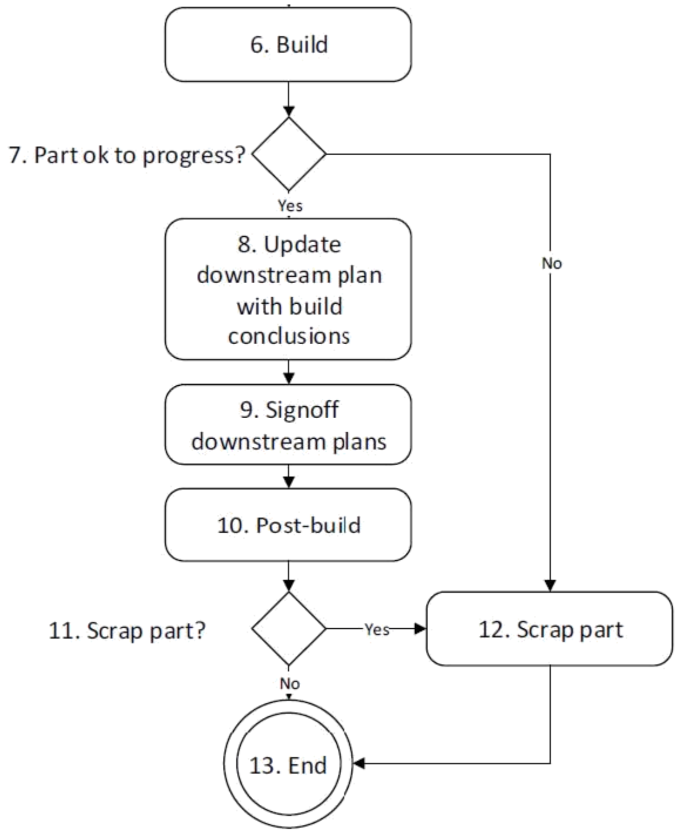
1. Provides similar guidance that aligns with AM application engineer recommendations (whilst the level of guidance may be less, it should not be contradictory).

2. Provides feedback in a timely manner enabling a more efficient design process.

3. Be easy and intuitive to use.

4. Enables parts to be built satisfactorily in fewer iterations (ideally right first time).





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DESIGN INTERROGATION TOOL (DIT)

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DESIGN INTERROGATION TOOL (DIT)

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CAD types:

AVEVA™ MARINE
CATIA
IGES
Rhinoceros
SOLIDWORKS
INSPIRE solidThinking®
creo®
AUTODESK® INVENTOR®
INTERGRAPH®
SIEMENS NX

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ORIENTATION

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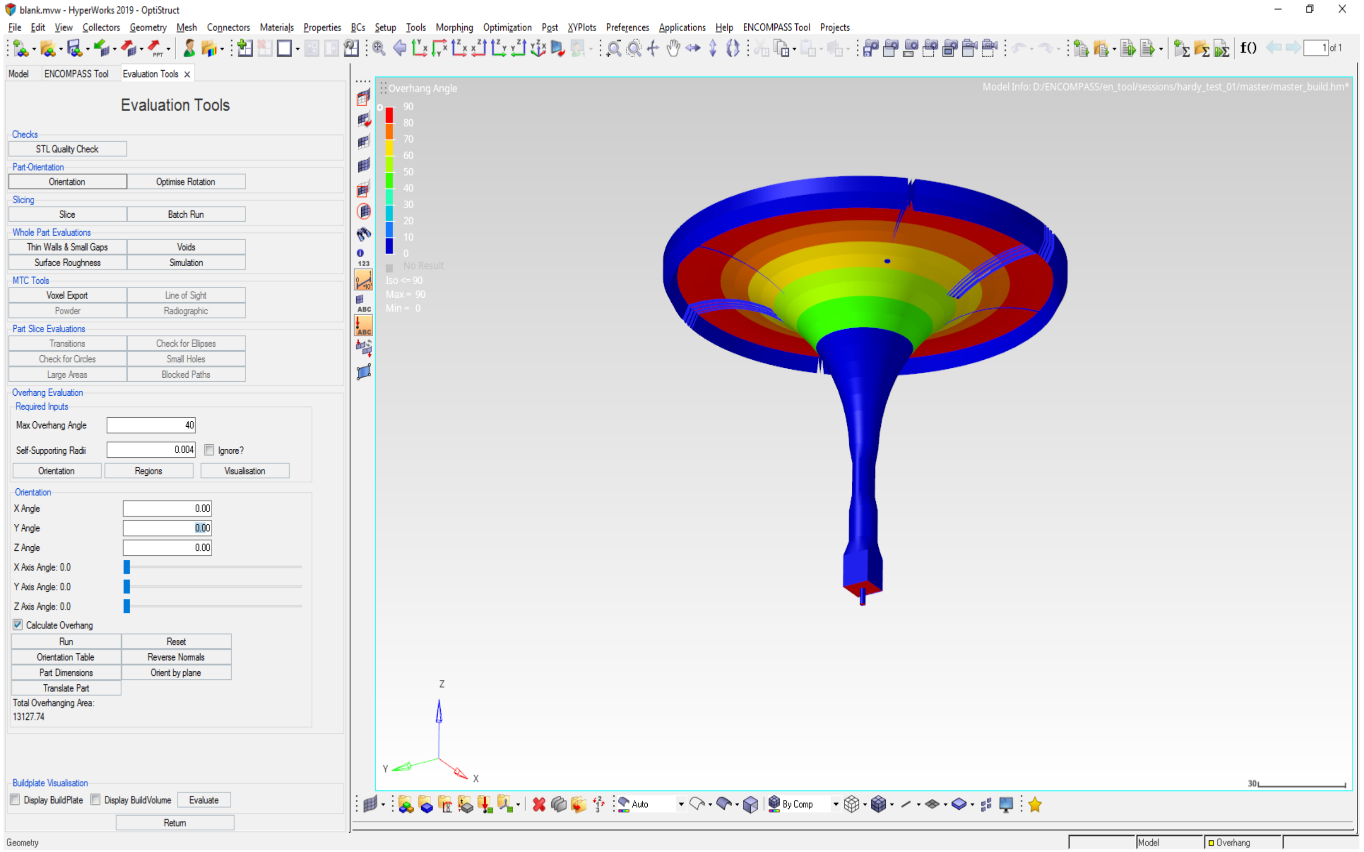

WHAT

- ✓ The orientation tool calculates the angle of each geometry facet relative to the build direction.
- ✓ Angles are presented as a contour to easily show overhanging regions.
- ✓ The build direction is always assumed to be the positive Z axis.

WHY

Overhangs are important to identify as they represent regions where heat cannot be easily dissipated and therefore supports are required to remove excess heat and to prevent distortion of the printed layers.

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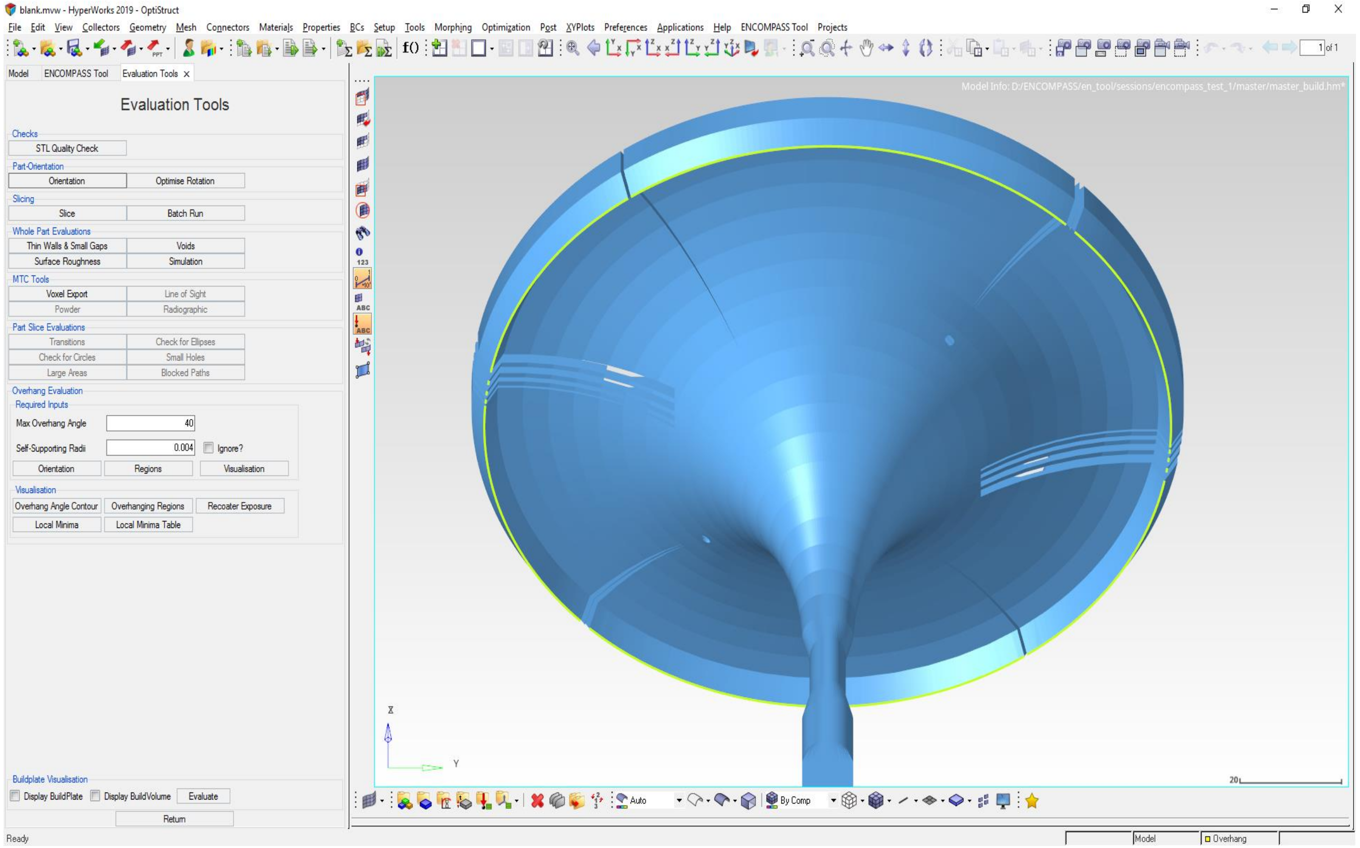
ORIENTATION – LOCAL MINIMA



WHAT

- ✓ Local minima are downward facing edges of the part geometry that require support but will not be supported by default as the adjacent faces are not classed as overhanging surfaces.

WHY

- ✓ Having local minima will result in material being printed without any underlying support or any support from adjoining part geometry, this leads to various build issues.

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ORIENTATION – RECOATER EXPOSURE

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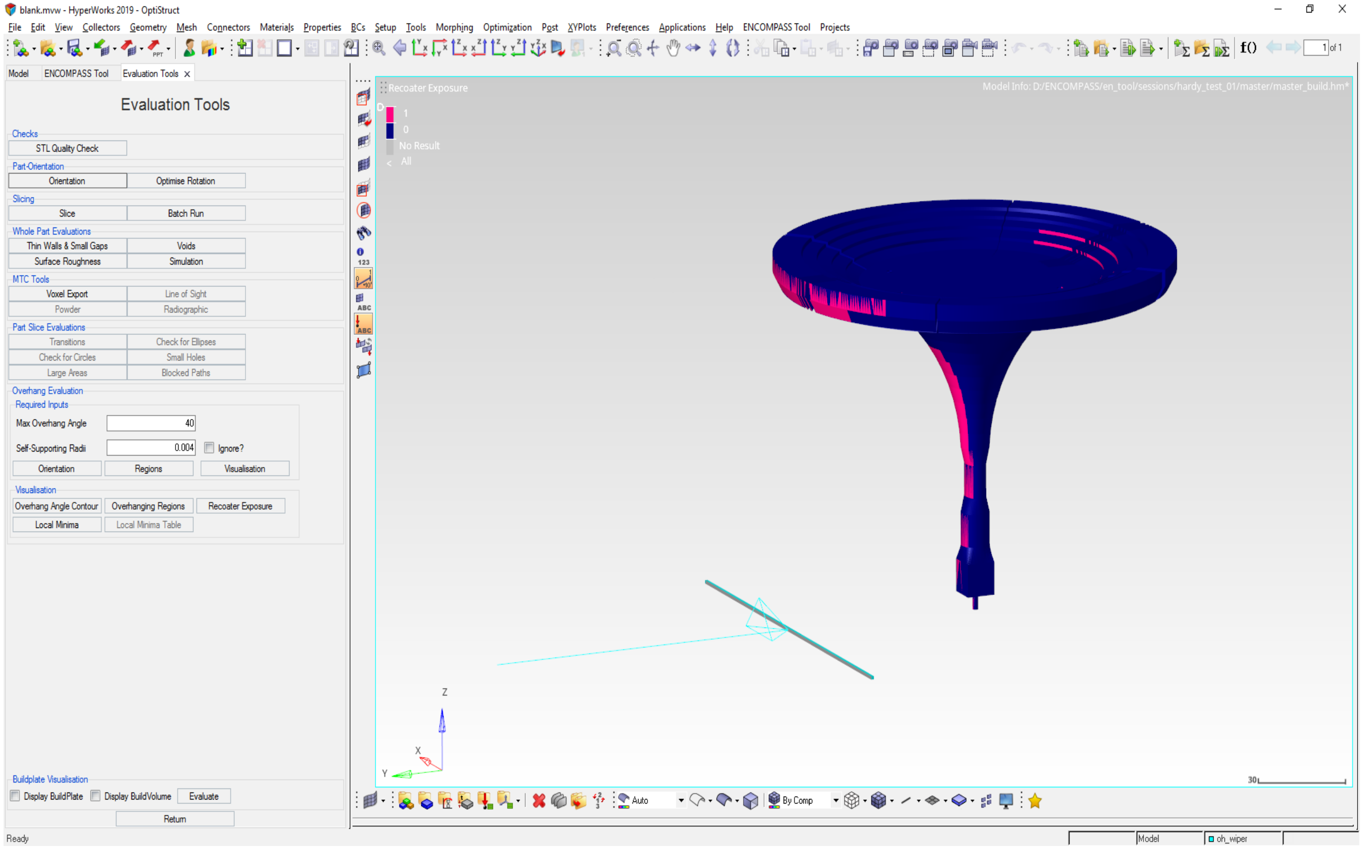

WHAT

- ✓ Shows facets exposed to the wiper direction (-Y axis) that also have a normal pointing in the negative Z direction.

WHY

Facets of the geometry that exhibit the above characteristics can lead to build issues where the wiper may get caught on the feature due to distortion.

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OPTIMISE ORIENTATION

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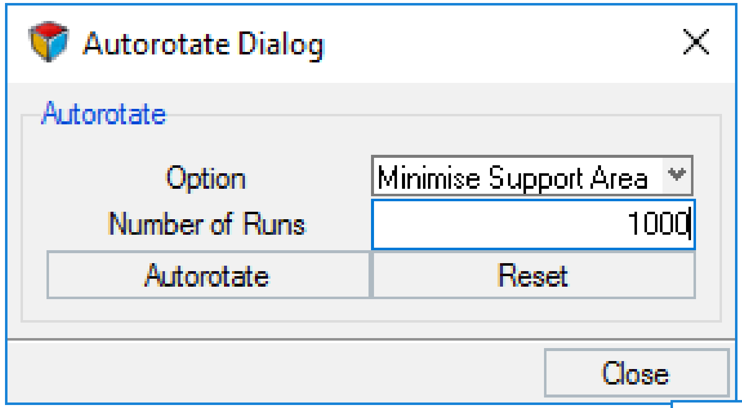

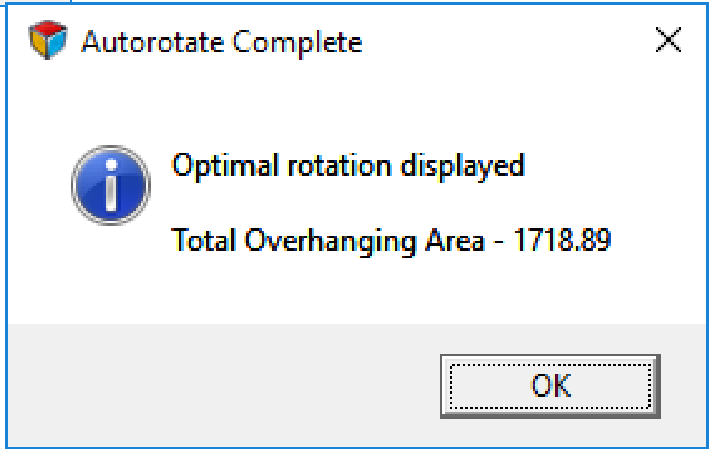

WHAT

- ✓ This tool will run a user defined amount of rotations to check for an optimal orientation for the part. This will return the part at the orientation with the lowest Total Overhanging Area.
- ✓ When complete the optimal orientation will be shown on screen.

WHY

Orienting the part to minimise overhangs reduces the need for supports, which has time and cost benefits in build and post-processing. Minimising is difficult to perform manually, hence having an automated tool to achieve this.

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THIN WALLS & SMALL GAPS

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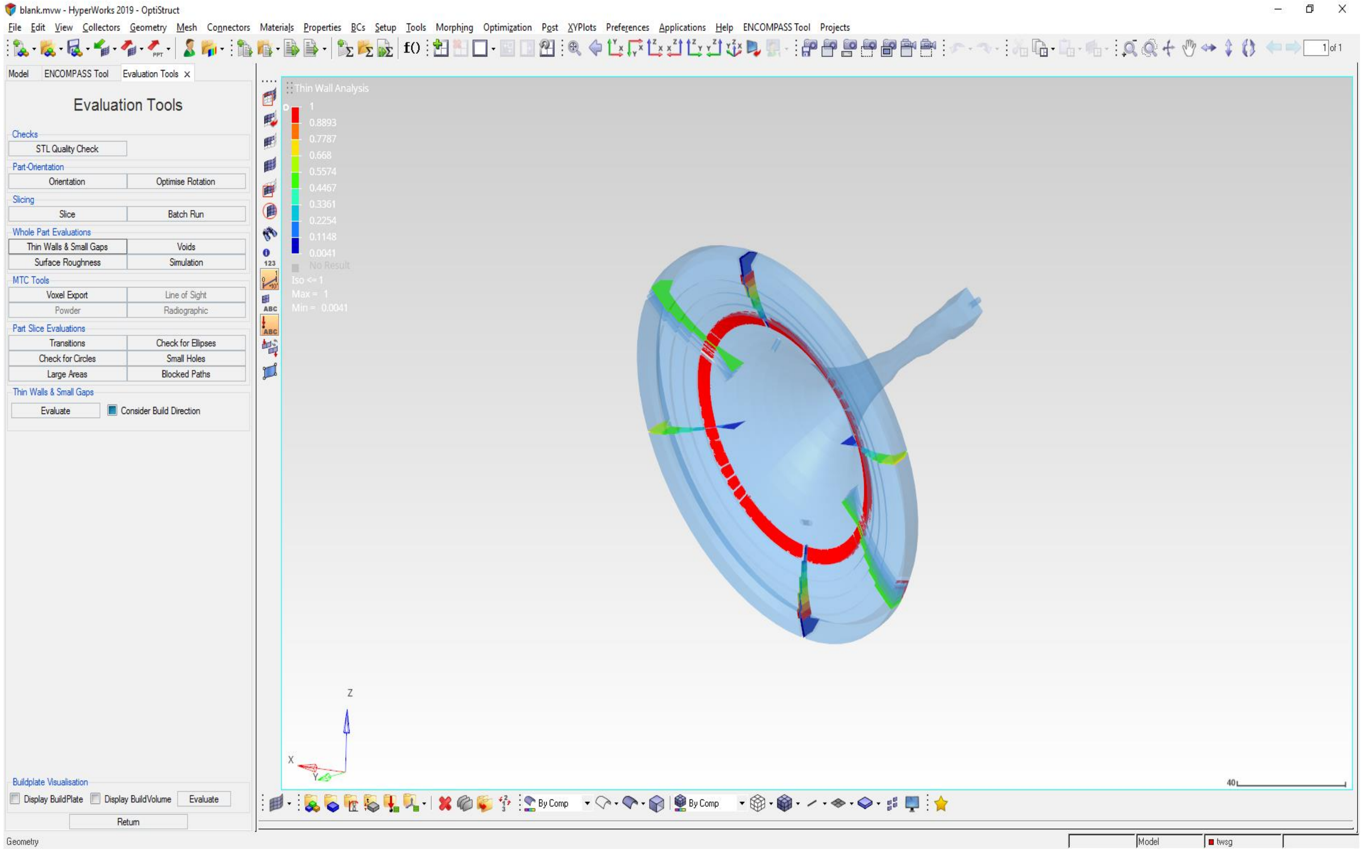

WHAT

- ✓ This evaluation identifies regions of the part geometry that represent thin walls or small gaps that are thinner than a specified limit.

WHY

- ✓ Thin walls can be problematic in build as they may lead to distortion. Thin (small) gaps can result in that gap being unintentionally fused together during build, which may compromise intended part performance.

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SURFACE ROUGHNESS

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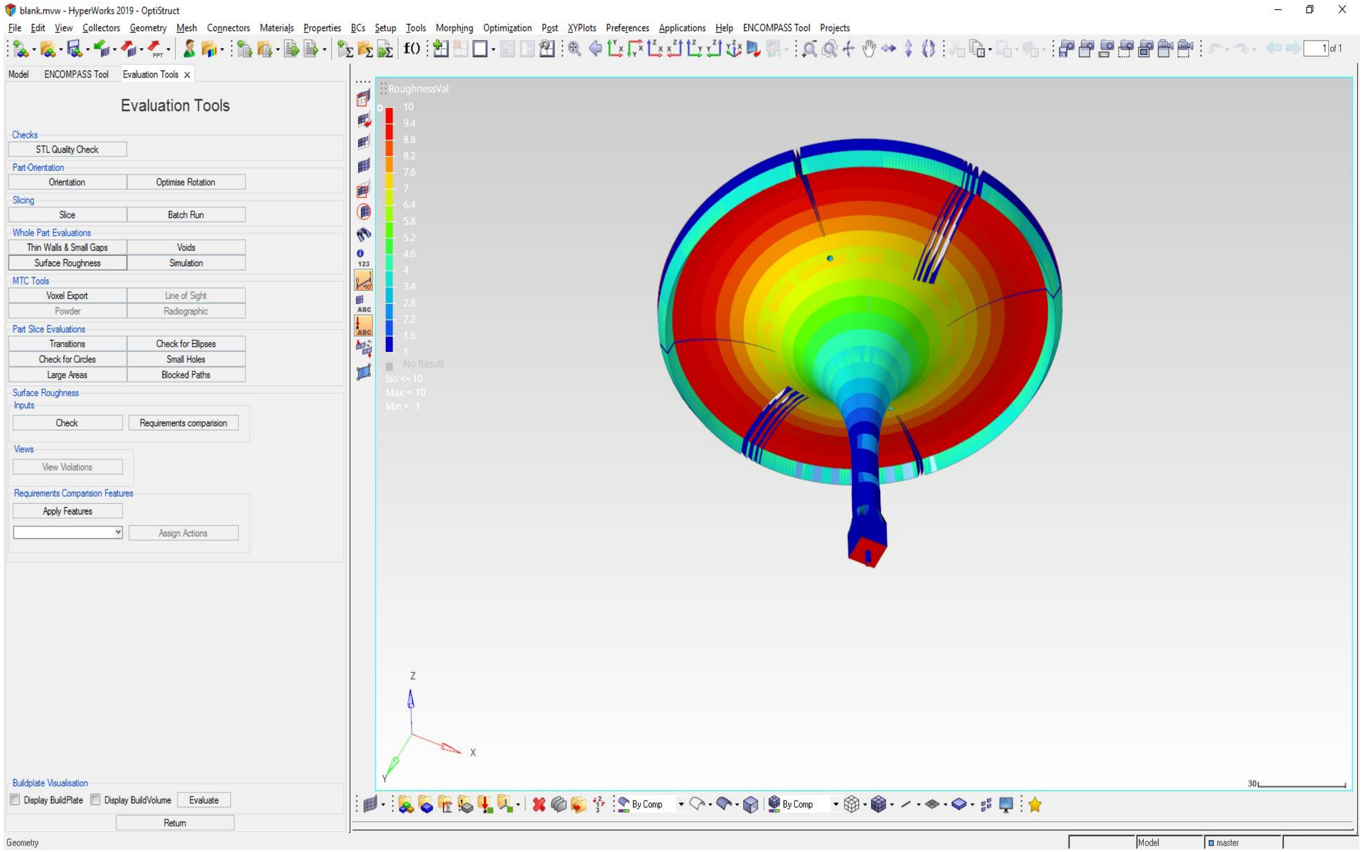

WHAT

- ✓ The surface roughness (SR) tool calculates the angle of each facet relative to the positive and negative build direction.
- ✓ These angles are then compared to a look-up table that relates angle to predicted surface roughness.
- ✓ These roughness values are then contoured on the part.

WHY

- ✓ Part specifications typically dictate surface finishes that must be achieved on the finished part. This evaluation allows the user to estimate if any of these surface finish requirements will be violated and if surface finishing will be required.

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VOIDS

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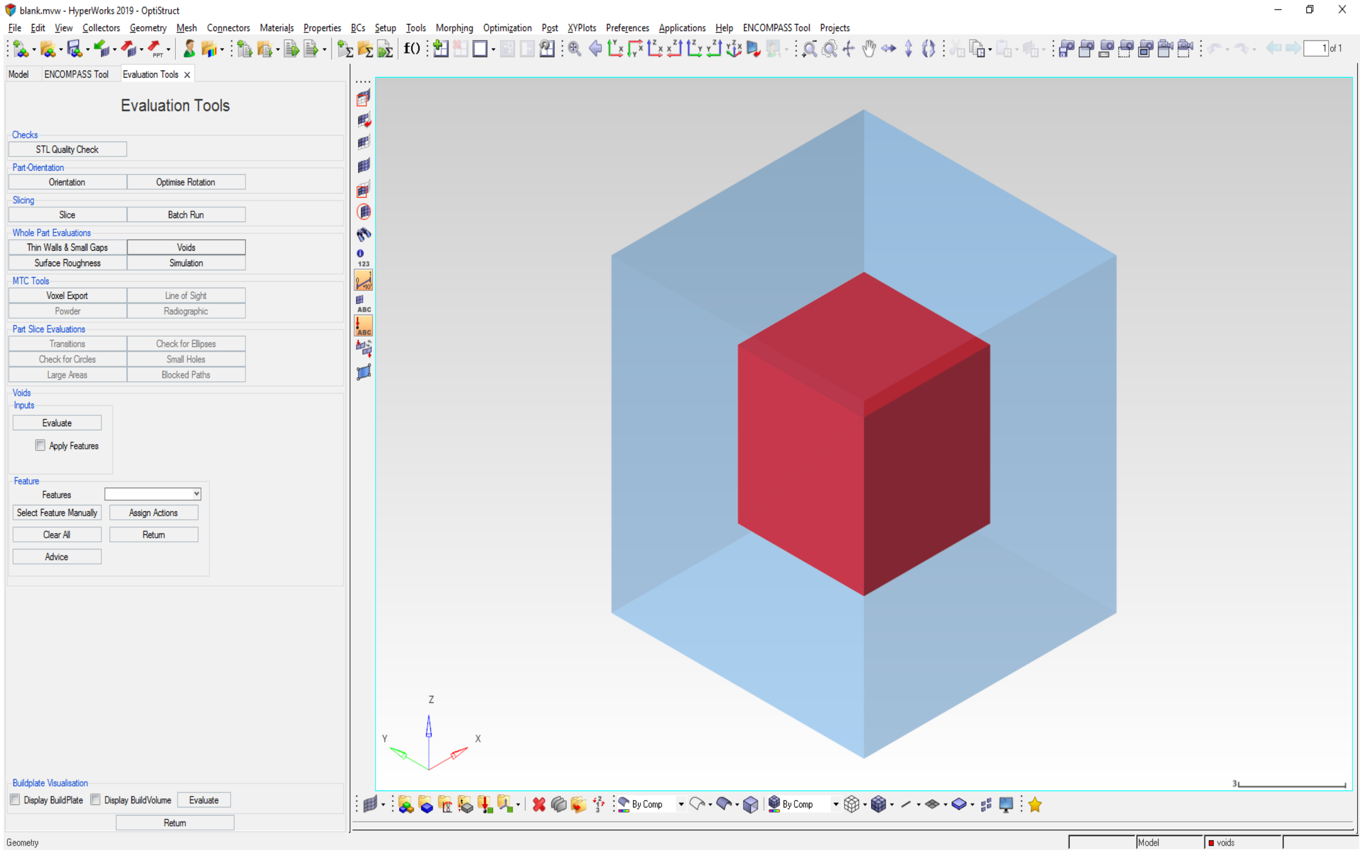

WHAT

- ✓ Detects fully enclosed volumes within the geometry and highlights these to the user

WHY

- ✓ Fully enclosed volumes (voids) in the geometry will result in powder being trapped and are therefore undesirable.

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VOXEL EXPORT

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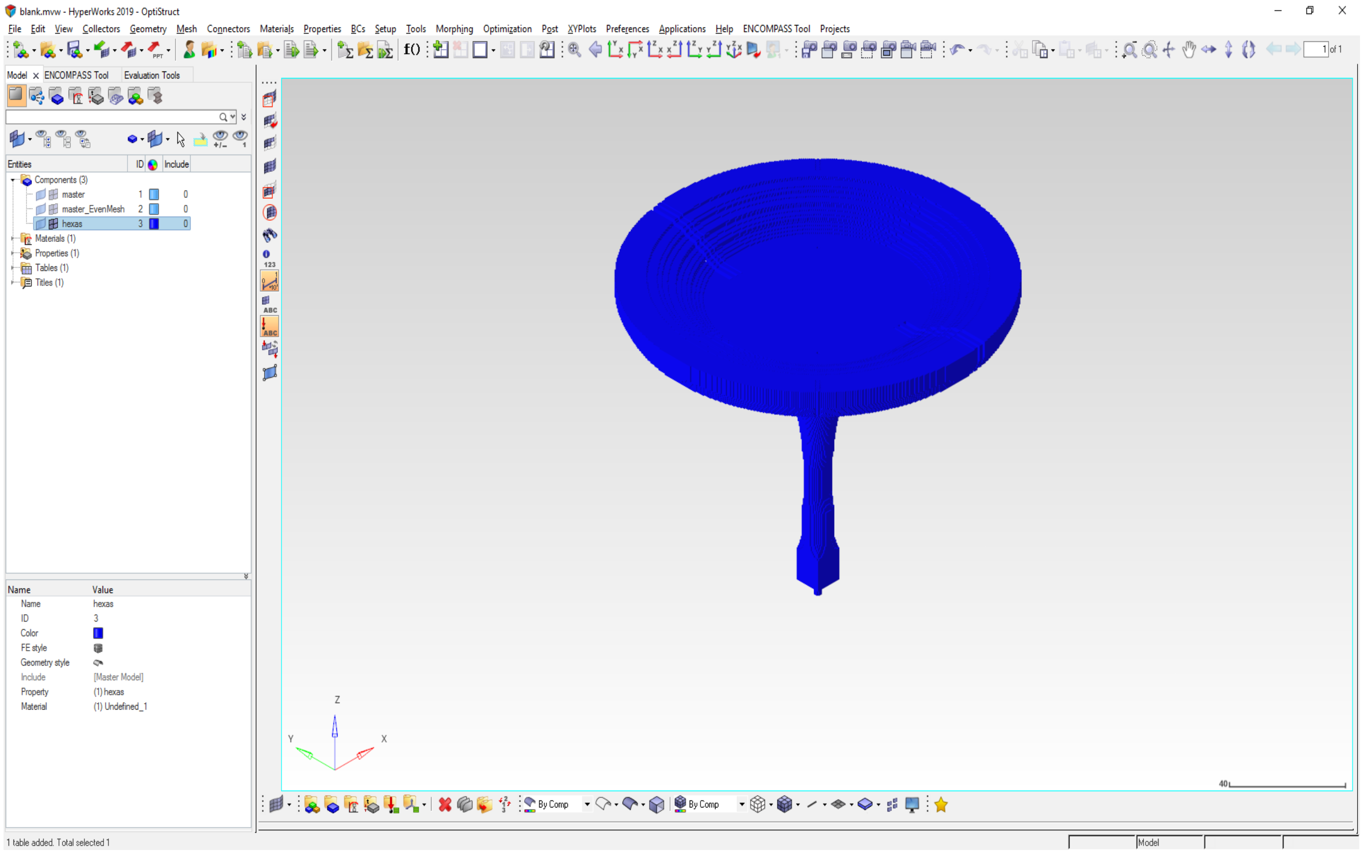

WHAT

- ✓ Exports a Voxel mesh of the component.
- ✓ This is stored locally for use by external DIT tools.

WHY

- ✓ A voxel mesh representation of the part geometry is necessary to perform certain evaluations.

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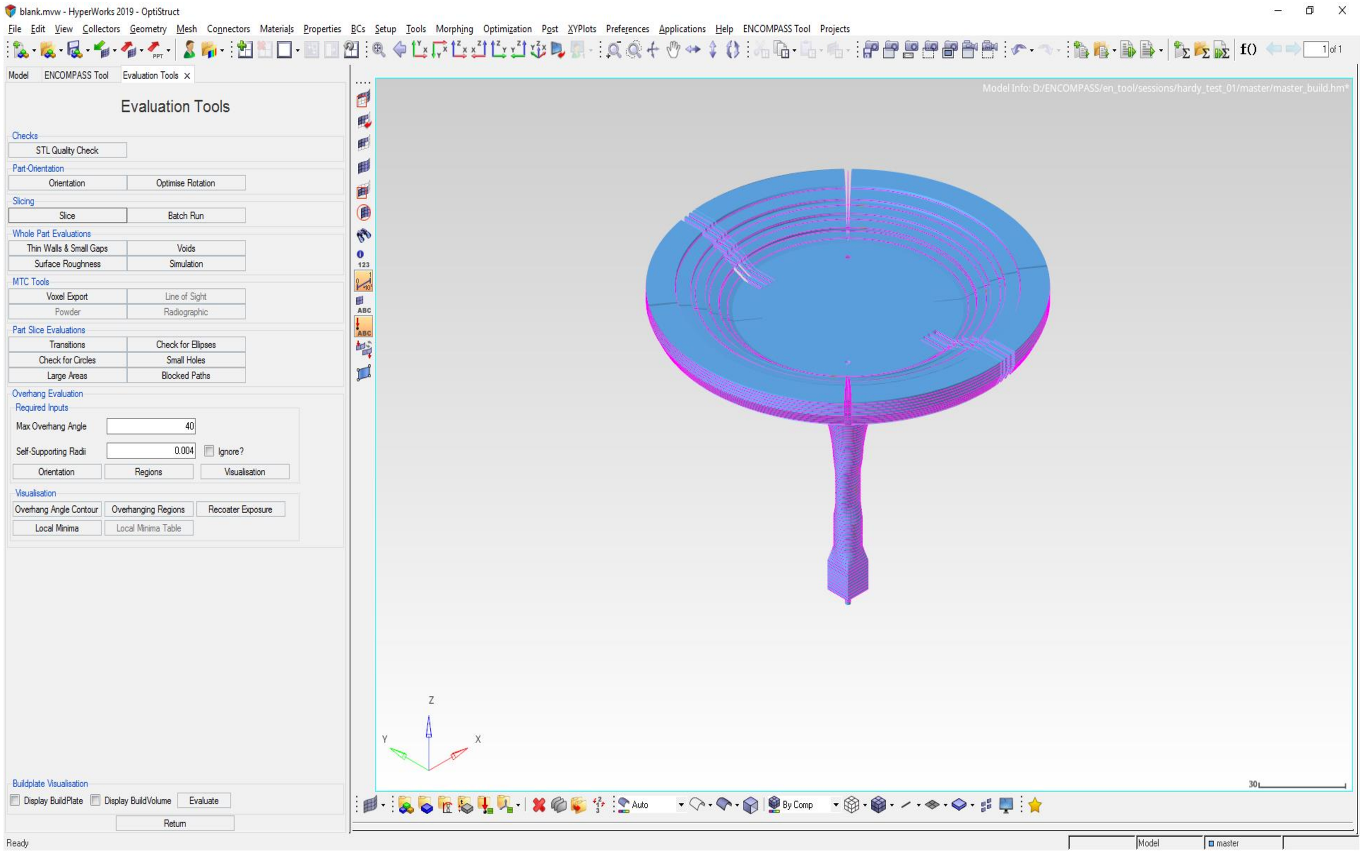
SLICING



WHAT

- ✓ Slices the part into layers. Slice size is defined in the setup stage. Allows for further evaluations to be carried out which work on the slice geometry.

WHY

- ✓ Slicing the geometry converts that geometry into a format that matches what will be seen by the build process.
- ✓ This enables slice based geometrical evaluations to be performed.

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TRANSITIONS

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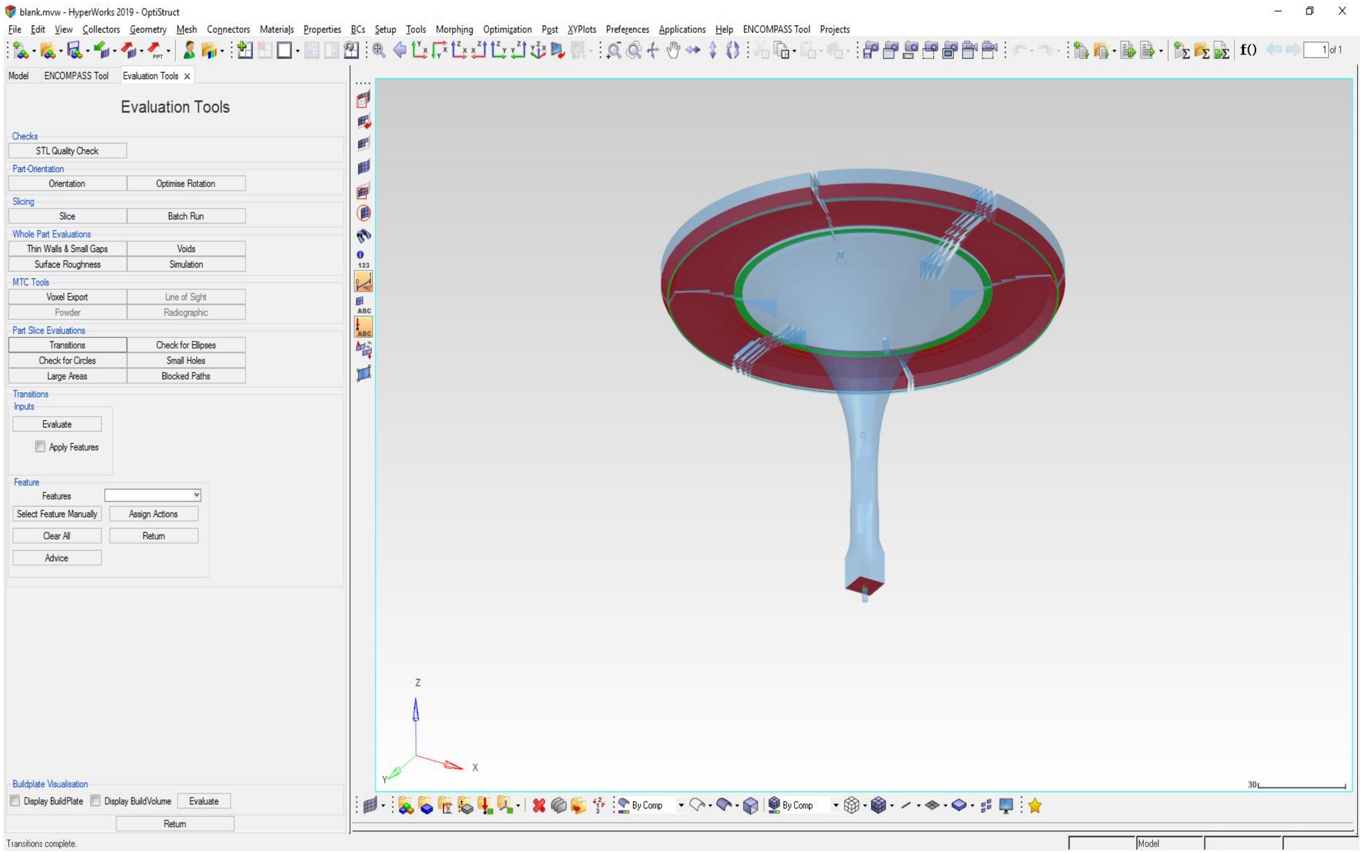

WHAT

- ✓ Transitions highlights regions of slices which exceed an area ratio from one layer to the next. If the ratio of one layer to the next is exceeded it is highlighted to the user. The ratio is set by the IDDS.

WHY

- ✓ Rapid transitions from slender to bulky geometry can cause heat dissipation issues leading to high stresses, distortion and potential build failure. It is therefore import to highlight these regions so they can be accounted for.

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ELLIPSES

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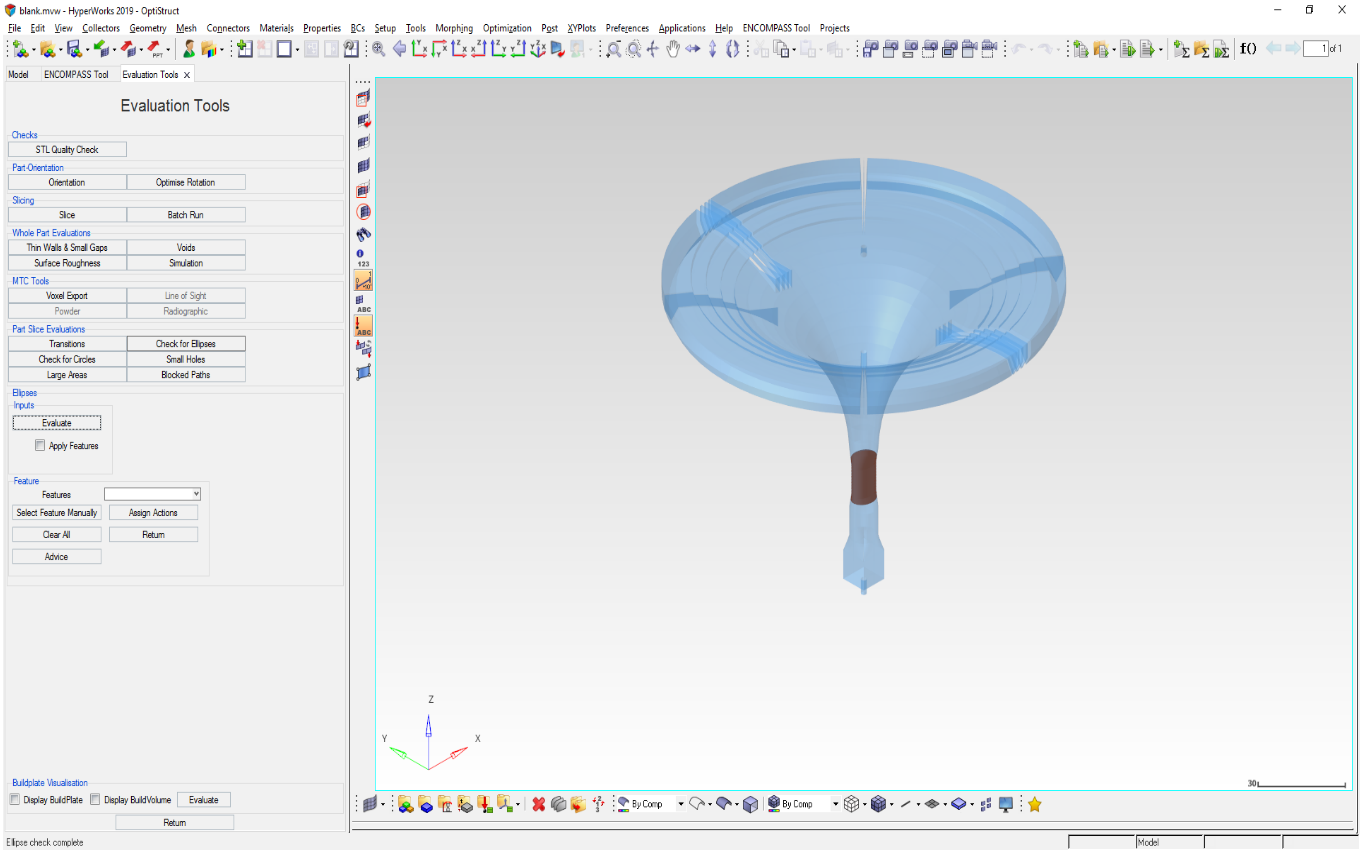

WHAT

- ✓ The ellipse evaluation finds ellipses in the model on each slice. These are then highlighted to the user.

WHY

- ✓ Having ellipses in the slice geometry allows specific scan strategies to be applied to those ellipses, resulting in a better quality build.

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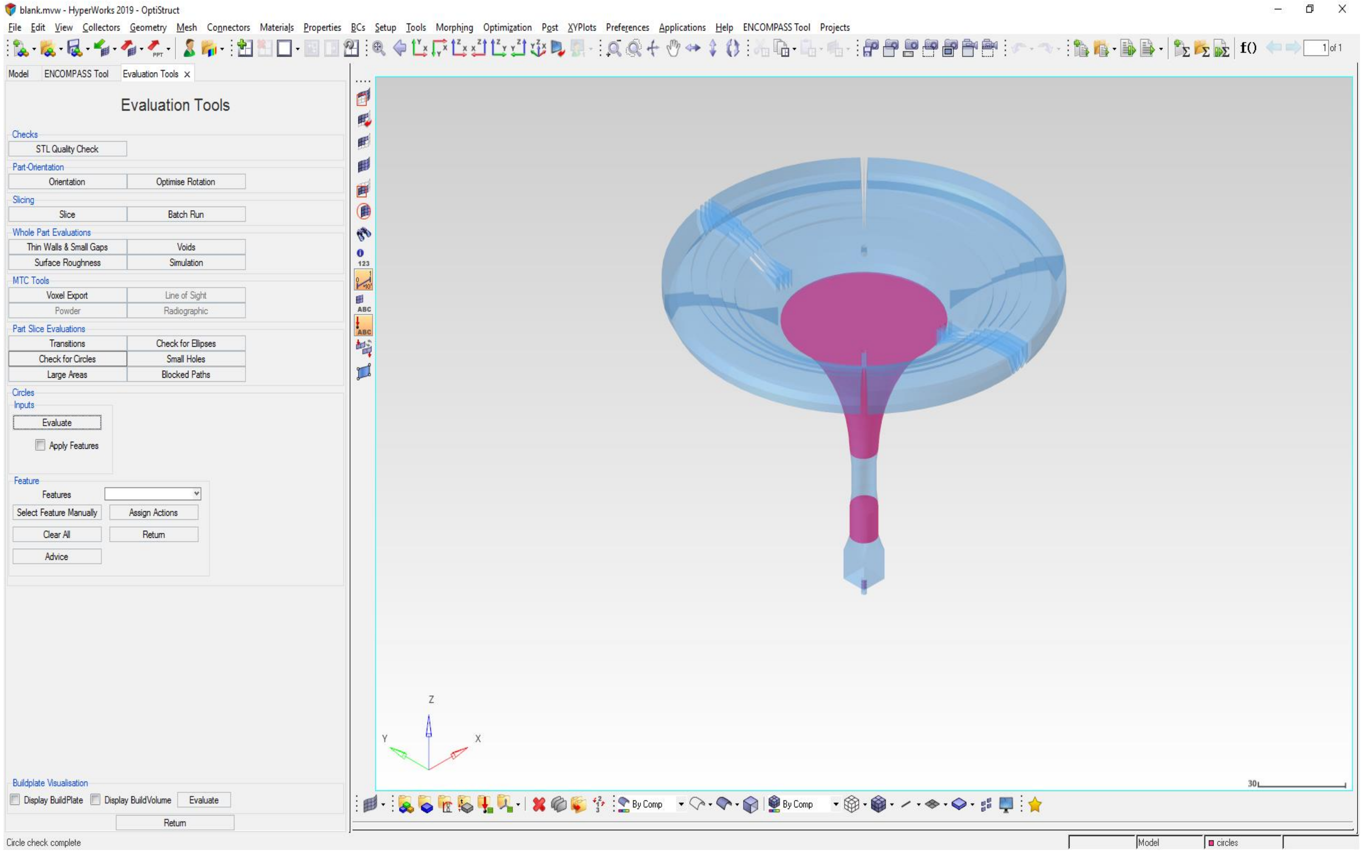
CIRCLES



WHAT

- ✓ The circle evaluation finds circles in the model on each slice. These are then highlighted to the user.

WHY

- ✓ Having circles in the slice geometry allows specific scan strategies to be applied to those circles, resulting in a better quality build.

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SMALL HOLES

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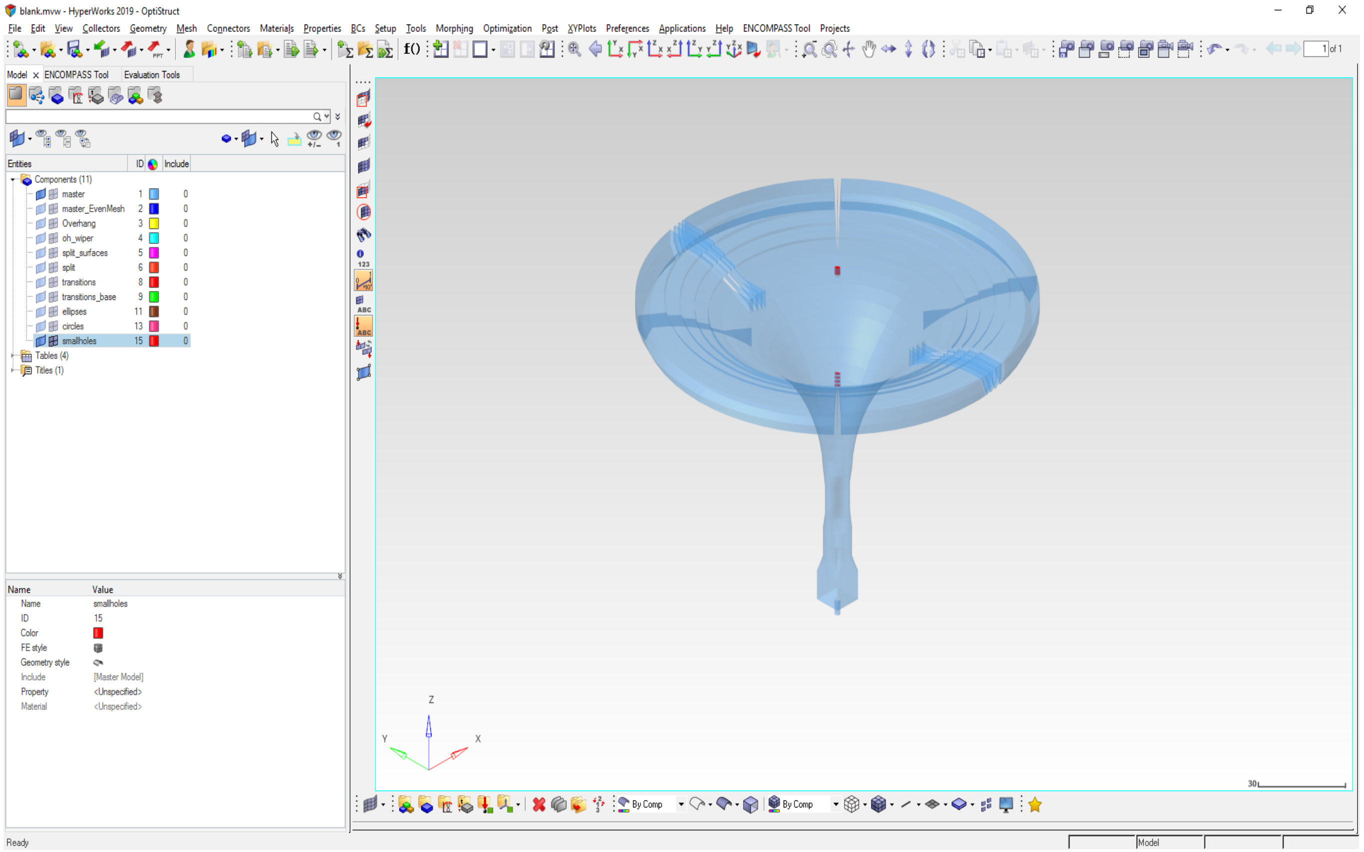

WHAT

- ✓ Will locate any holes defined as too small by the IDDS system.
- ✓ Scans each slice and locates holes in the geometry.
- ✓ Any hole below the requirements will be highlighted to the user.

WHY

- ✓ Small holes may not build properly due to them being too small relative to the laser beam geometry, powder size and melt characteristics of the material.

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LARGE AREAS

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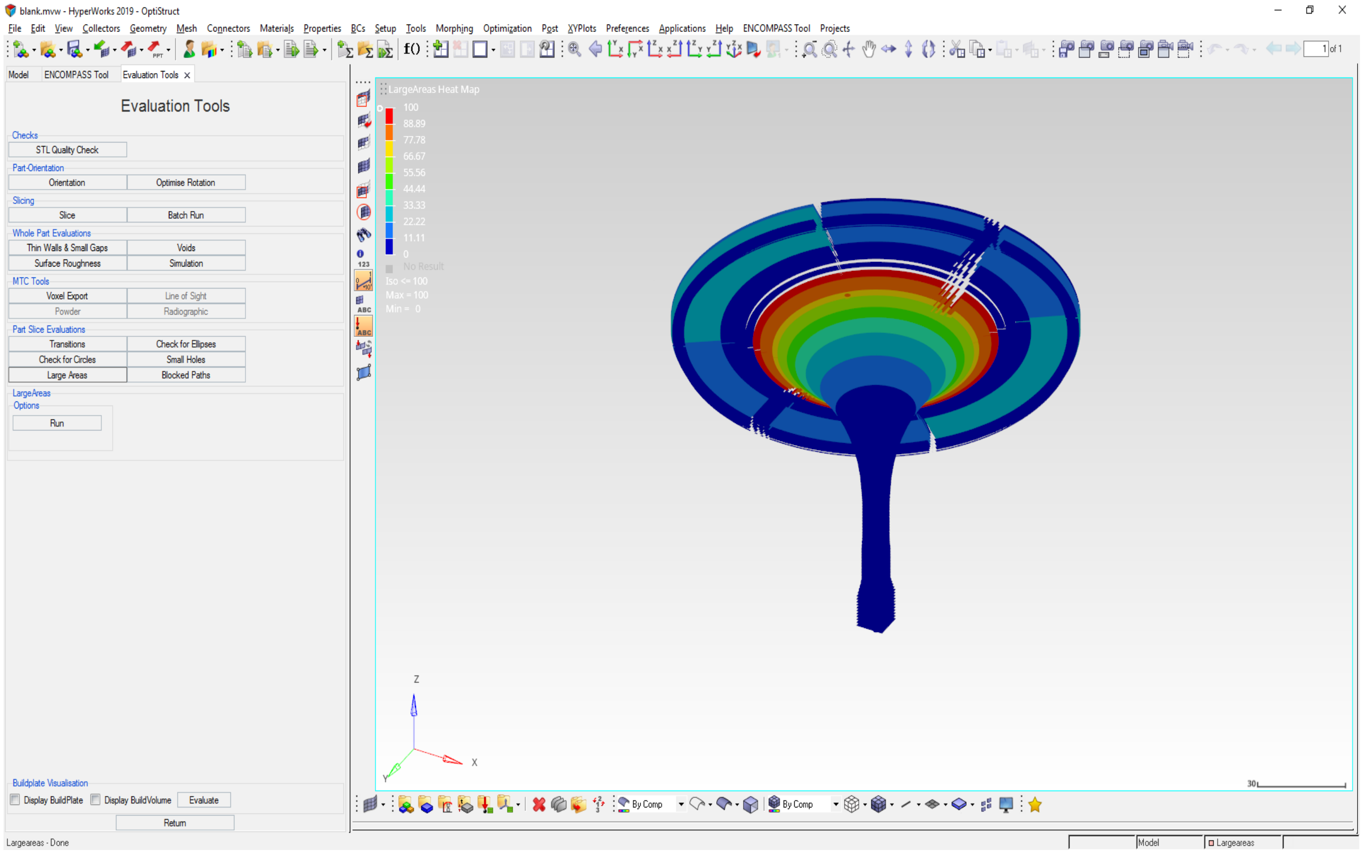

WHAT

- ✓ Calculates the area of each surface within each slice. Saves the calculated areas, normalises the data and presents as a contour. Used to demonstrate concentrations of larger areas in the part.

WHY

- ✓ Relatively large slice areas will mean longer laser exposure times to build that slice, which means relatively greater heat input into the part at that slice.
- ✓ Such an evaluation can therefore be used as a quick way to identify on which slice heat related distortion issues may occur.

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BLOCKED PATHS

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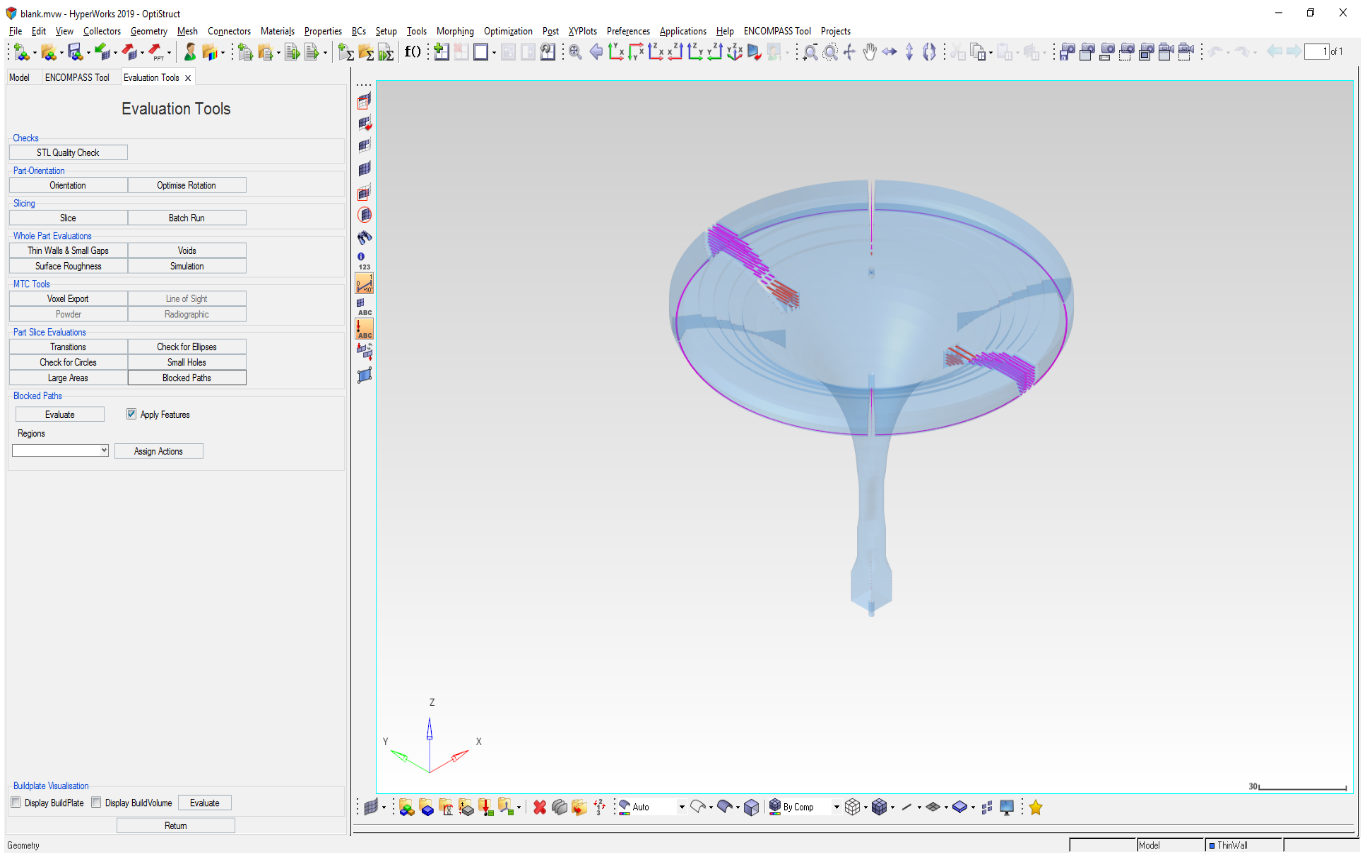

WHAT

- ✓ The boundary lines of each slice are evaluated against a circle representative of the laser diameter. Where the circle will not fit reveals blocked paths that cannot be built.
- ✓ These blocked paths indicate thin walls, small areas and sharp corners.

WHY

- ✓ For parts where geometrical accuracy and very fine features are import, this evaluation identifies regions that will not build correctly due to blocked paths.

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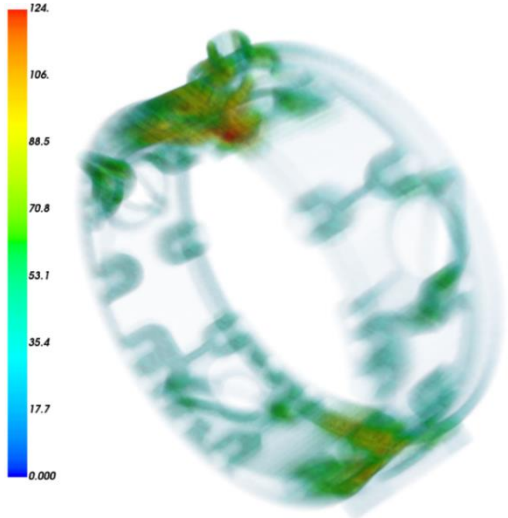
POST PROCESS

Inspection Simulation

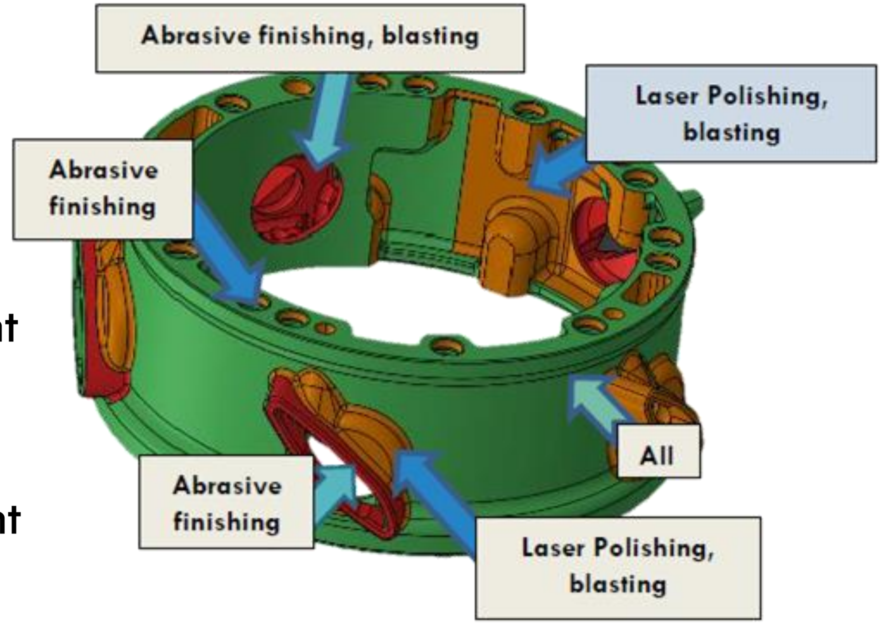
- Evaluate line of sight
- Detectability of defects
- Equipment capabilities



Post-process Simulation

Surface roughness requirements and equipment capabilities

Heat treatment cycle for distortions



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ENCOMPASS CASE STUDIES

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AEROSPACE CASING

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ITP Aero

EVALUATION	RESULT	OBSERVATIONS
Surface Roughness	Actions stated	Build surface roughness would not comply with drawing requirements.
Simulation	Actions stated	Simulation shows some distortions in some areas due to transitions.
Transitions	Actions stated	Major transitions observed in several areas. Orientation was correct as supports are required to avoid distortion.
Large areas	Actions stated	Largest area was identified. A vast transition is observed close to it.

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AEROSPACE CASING – REDISIGN?

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REF.	EVALUATION STAGE	GEOMETRY FEATURE	ACTION DESCRIPTION	REDESIGN?
1	Surface Roughness	General	Post-Processing: Polishing or blasting process required to improve surface roughness.	N/A
2	Transitions/ Overhangs	Top & bottom flange holes	Design: Modify angle of internal faces to machine of holes at top and bottom flanges.	Yes
3	Transitions/ Overhangs	Top & bottom flange holes	Design: Adapt the transitions of the holes surrounding material avoiding overhanging areas	Yes
4	Transitions	Bottom flange	Design: Keep current orientation due to major distortion. Supports should be rigid enough.	N/A
5	Transitions/ Large Areas	Bottom flange to casing	Design: Avoid introducing much material in transition from bottom flange to casing	Yes
6	Transitions/ Overhangs	Struts bottom area	Design: Add material to avoid overhanging area, and smoother transition.	Yes

REF.	EVALUATION STAGE	GEOMETRY FEATURE	ACTION DESCRIPTION	REDESIGN?
7	Transitions/ Simulation	Casing and struts area	Design: Section area should be decreased but keeping smoother transitions.	Yes
8	Transitions/ Simulation	Casing and struts area	Design: Select with AM expert the appropriate wall thickness able to manufacture.	Yes
9	Transitions/ Simulation	Casing and struts area	Design: Adapt circular extrusions between struts and casing.	Yes
10	Transitions/ Overhangs	Internal casing area	Design: Adapt circular holes at internal casing area to an auto-support shape if possible	Yes
11	Transitions/ Overhangs	Struts internal chamber	Design: Modify top area of the strut chamber to an auto-support shape.	Yes
12	Transitions	Struts top hole	Design: Adapt struts top holes to new casing section design keeping smoothness.	Yes
13	Transition/ Overhangs	Casing – top flange external transition	Design: Apply smoother transition.	Yes

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AEROSPACE CASING – THE RESULTS

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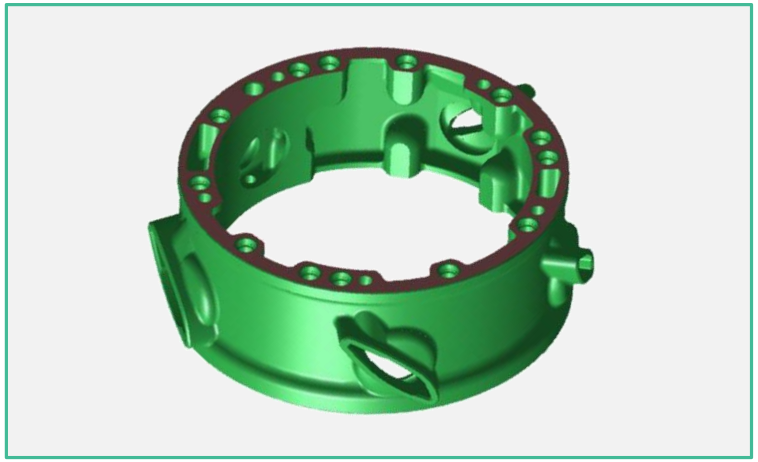
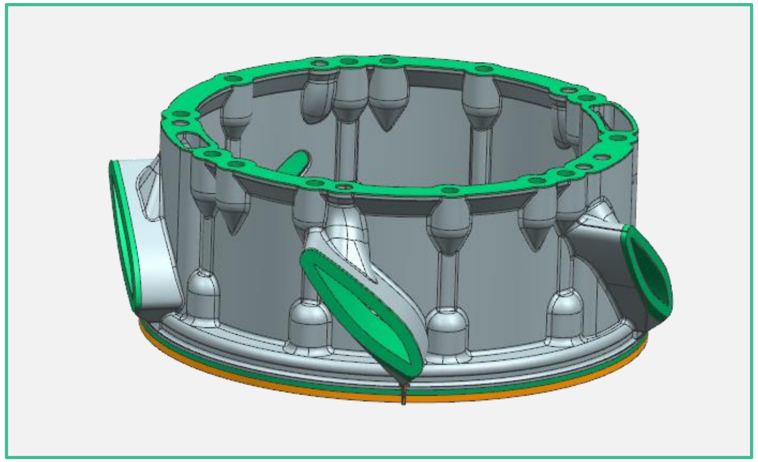


Initial design



Optimised Design after IDDS iteration

Optimised Part manufactured

ITP Aero

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AEROSPACE BRACKET

EVALUATION	RESULT	OBSERVATIONS
Orientation	Actions stated	Orientation of the part is not the best position. 3 results were obtained.
Surface Roughness	Actions stated	Build surface roughness would not comply with drawing requirements.
Blocked Path	Actions stated	Was detected that the laser cannot reach some areas of the part.
Transitions	Actions stated	Major transitions observed in several areas. Orientation was correct as supports are required to avoid distortion.

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AEROSPACE BRACKET

ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM

EVALUATION	RESULT	OBSERVATIONS
Circles & Ellipses	Actions stated	The contour scanning strategy could be applied, as in its current form in cannot be applied to partial curves.
Large Areas	Actions stated	Some areas of the component are likely to retain heat through the build process as a result of longer exposure to the energy source.
Radiographic	Actions stated	Radiographic shows areas not acceptable based upon the stress fields.
Support Generation	Actions stated	Supports were deemed too high, there fore fine supports were used.

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AEROSPACE BRACKET

REF.	EVALUATION STAGE	GEOMETRY FEATURE	ACTION DESCRIPTION	REDESIGN?
1	Orientation	General	Re-optimize component with 45° overhanging angle constraint	Yes
2	Surface Roughness	General	Assess resulting surface roughness for suitability Identify where machining will be required Add stock as required	Yes
3	Blocked Path	Highlighted Regions	Review regions and determine if acceptable without re-design	No
4	Transitions	Bolting Points	Remove bolt holes from the build model	Yes

REF.	EVALUATION STAGE	GEOMETRY FEATURE	ACTION DESCRIPTION	REDESIGN?
5	Circles & Ellipses	Highlighted Regions	Review highlighted regions and determine whether special parameters to be applied	No
6	Large Areas	General	Review the criteria in the IDDS, perform evidence gathering exercise. Remove the bolt holes in the part to remove the bridging and smooth transitions.	Yes
7	Radiographic	Highlighted Regions	Determine if identified invisible regions acceptable at lower power	No
8	Support Generation	General	Review generated support structure and determine cost effectiveness	Yes

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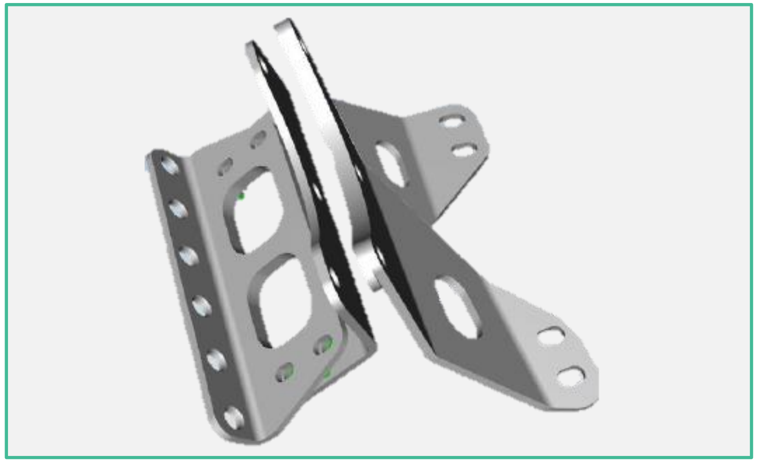
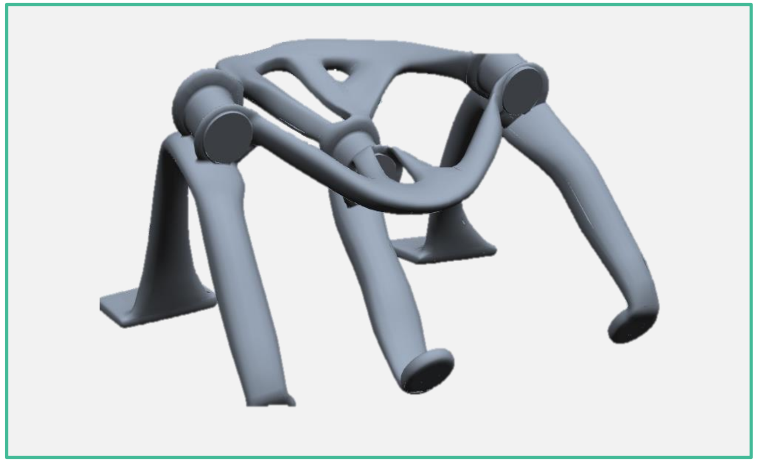
AEROSPACE CASING – THE RESULTS



Initial design

Initial Design Iteration



Optimised Design after IDDS iteration

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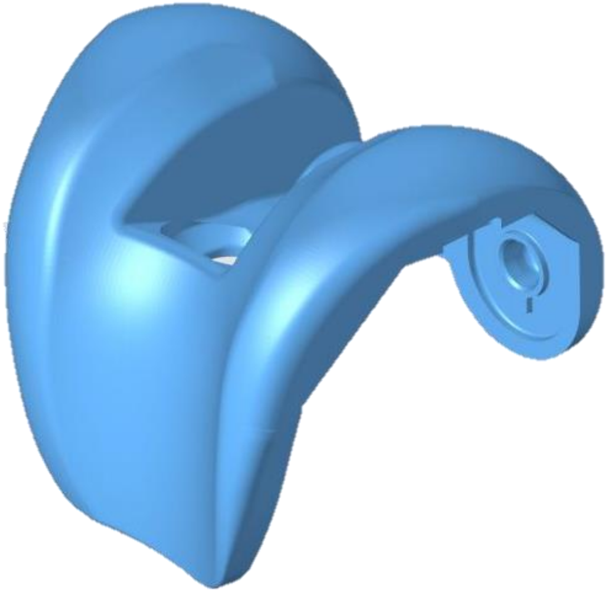
SIGMA CRUCIATE SUBSTITUTING (CS) FEMORAL



DePuy Synthes *People inspired*™

EVALUATION	RESULT	OBSERVATIONS
Thin walls & small gaps	OK	No Thin walls were detected in the evaluation part.
Voids	OK	No voids were found in the evaluation part.
Surface Roughness	Actions stated	Values of surface roughness did not appear realistic. Upon inspection of IDDS system. Only up skin values were inputted into the software. Expected down skin values were not implemented.
Line of sight	OK	Some areas of the component cannot be visually inspected, but it is acceptable based on design criteria.
Powder	OK	Software showed areas of trapped powder, however this can be easily cleaned.
Radiographic	OK	Part can be inspected if made from Ti64, however there would be issues with Inconel.
Simulation	Actions stated	Not provided as it did not run during test evaluation session.

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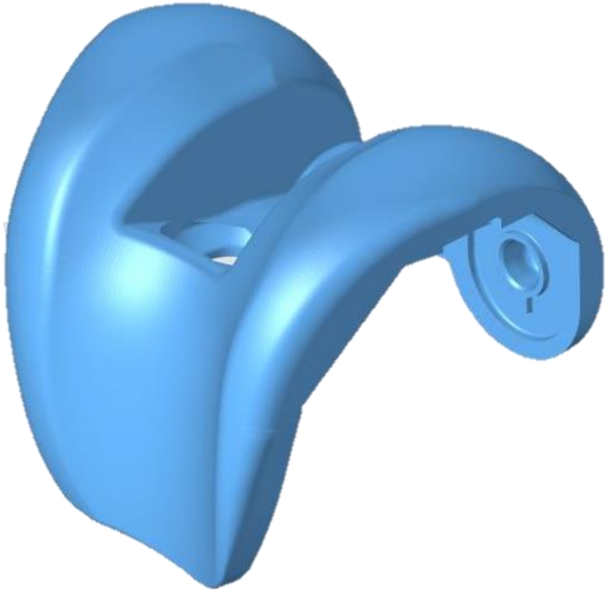
SIGMA CRUCIATE SUBSTITUTING (CS) FEMORAL

ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM



DePuy Synthes *People inspired*™

EVALUATION	RESULT	OBSERVATIONS
Blocked Path	OK	No blocked path detected.
Transitions	Actions stated	Major transitions observed in several areas. Orientation was correct as supports are required to avoid distortion.
Circles	OK	No relevant circle was identified.
Ellipses	N/A	No ESI license available during test evaluation. Not evaluated
Small Holes	OK	No small hole was detected.
Large areas	Actions stated	Largest area was identified. A vast transition is observed close to it.

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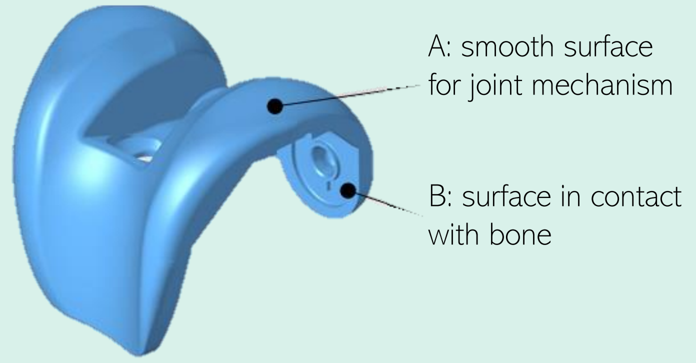
SIGMA CRUCIATE SUBSTITUTING (CS) FEMORAL

REF.	EVALUATION STAGE	ACTION DESCRIPTION	REDESIGN?
1	Surface Roughness	Post-Processing: Polishing or blasting process required to improve surface roughness.	Yes
2	Orientation	Target surface roughness not achievable with AM technology. Post-process step required, and optimal addition of support is required	No
3	Trapped powder	Ensure there are no regions where powder can be trapped in the component	Yes



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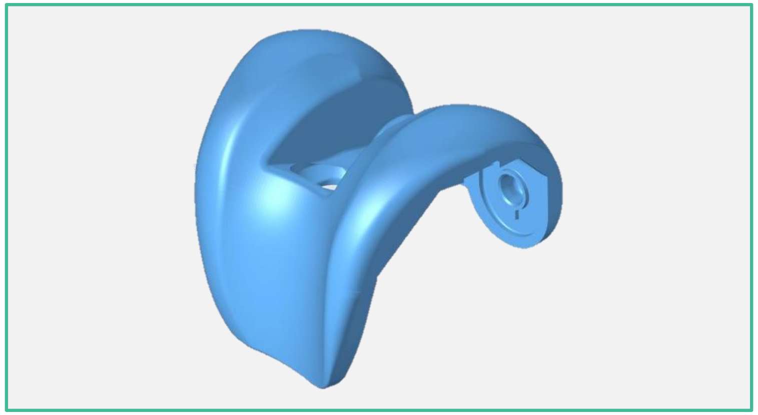
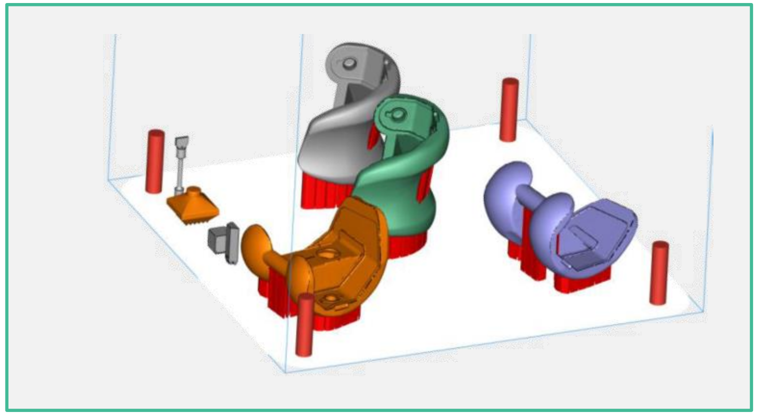
SIGMA CRUCIATE SUBSTITUTING (CS) FEMORAL

ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM





Initial design → Optimised Design after IDDS iteration → Optimised Part manufactured

DePuy Synthes *People inspired*™

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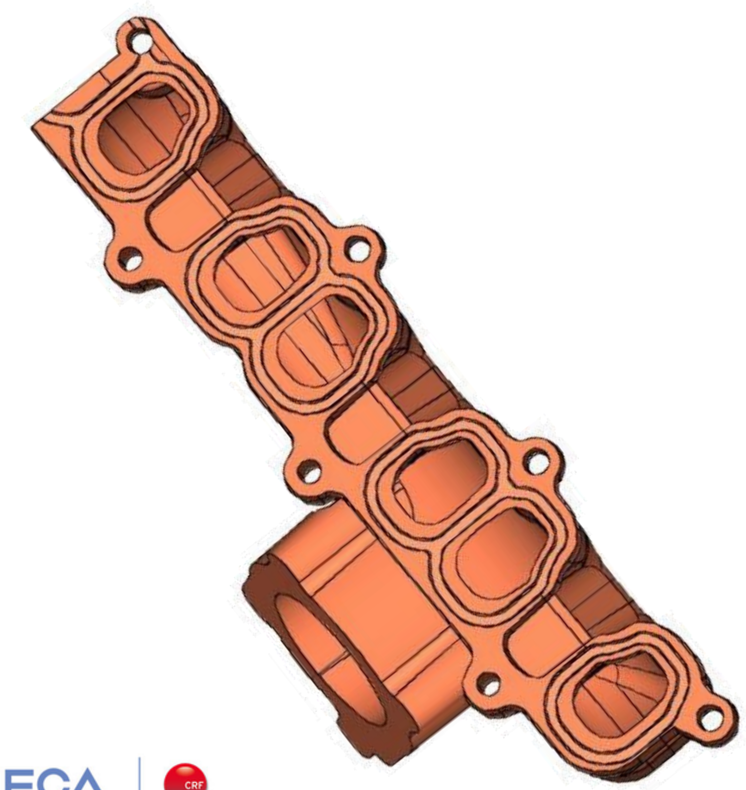
AUTOMOTIVE MANIFOLD

ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM



EVALUATION	RESULT	OBSERVATIONS
Overhang	Actions stated	Optimise Rotation -> need to consider volume fitting inside the platform volume (better UI could simplify the job analysis and modification)
Support	Actions stated	Keeping into account the component orientation, in order to remove internal support proper part orientation has been selected.
Circles	Actions started	Despite no critical circle was identified, in order to reduce the internal support, the final channel shape has been redesigned to be auto-support.

FCA
FIAT CHRYSLER AUTOMOBILES
CRF

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PHOTONICS21 FoF

AUTOMOTIVE MANIFOLD

ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM

REF.	EVALUATION STAGE	GEOMETRY FEATURE	ACTION DESCRIPTION	REDESIGN?
1	Surface Roughness	General	Post-Processing: Polishing or blasting process required to improve surface roughness.	N/A
2	Orientation	General	Design: identify improved orientation in order to minimize internal support needs	Yes
3	Transitions/ Overhangs	Channels flange holes	Design: Adapt the transitions of the holes surrounding material avoiding overhanging areas	Yes
4	Transitions/ Overhangs	Internal channels	Design: Adapt the internal channels shape in order to avoid internal supports	Yes
5	Transitions	Bottom flange	Design: Keep current orientation due to major distortion. Supports should be rigid enough.	N/A

REF.	EVALUATION STAGE	GEOMETRY FEATURE	ACTION DESCRIPTION	REDESIGN?
6	Transitions/ Overhangs	Struts internal collector	Design: Modify top area of the strut collector to an auto-support shape.	Yes
7	Transitions/ Large Areas	Bottom flange to casing	Design: Avoid introducing much material in transition from bottom flange to casing	Minimal
8	Transitions/ Overhangs	Struts bottom area	Design: Add material to avoid overhanging area, and smoother transition.	Minimal
9	Transition / overhangs	Holes	Design: hole features could be blanked off and post drilled	Yes
10	Transition / overhangs	Flanges	Design: channel flanges seal sets to be blanked off and post machined	Yes

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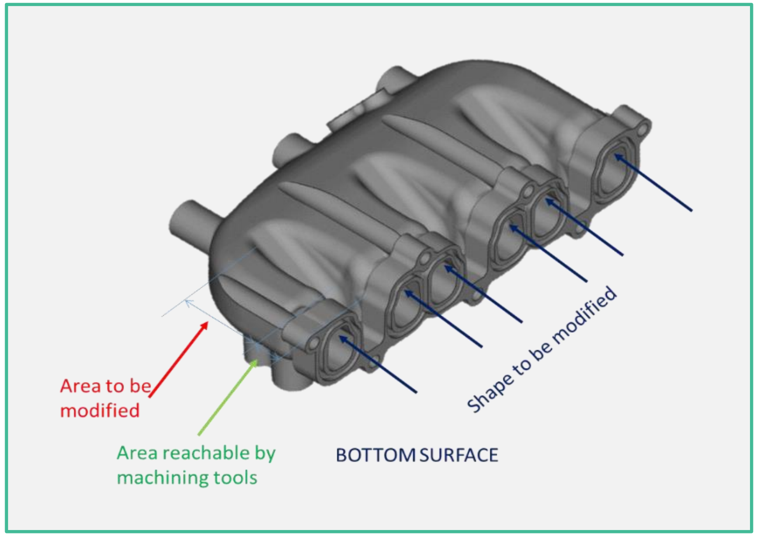
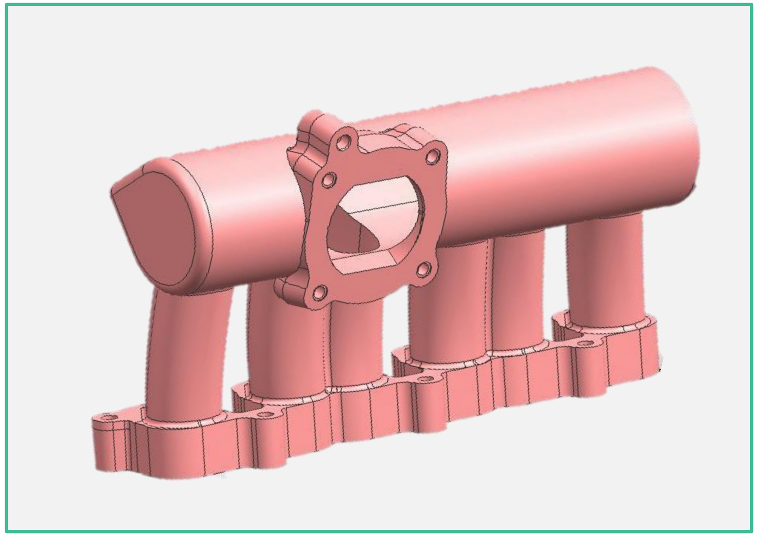
AEROSPACE CASING – THE RESULTS

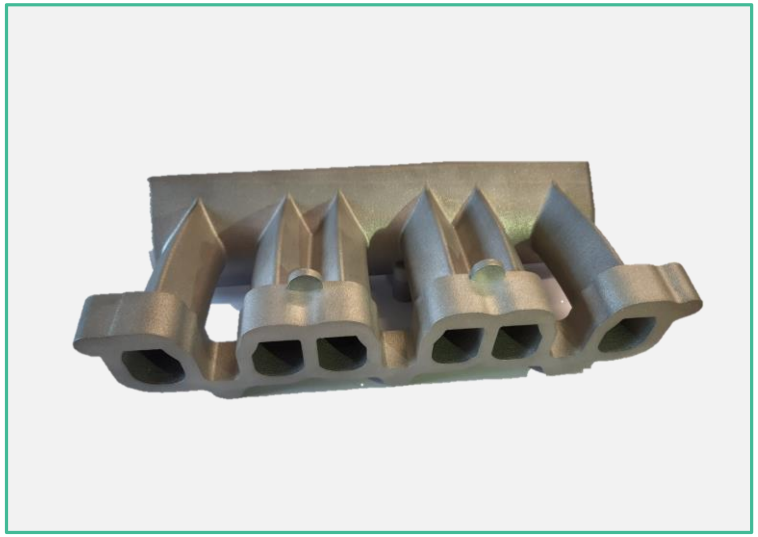
ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM



Initial design



Optimised Design after IDDS iteration



Optimised Part manufactured

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IMPACT

ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM

Manufacturing

- ✓ Reduce component weight
- ✓ Reduce production time
- ✓ Reduce energy usage
- ✓ Reduce costs of production

Standardization

- ✓ Contributions to standardization for Personnel Qualification/ Certification using ENCOMPASS Training Programme
- ✓ Contributions to standardization for PBF-LB

(e.g. Design, machines)

Environmental

- ✓ Reduce of the fuel consumption and emissions
- ✓ Smoother out gas flows
- ✓ Reduce noise

Social

- ✓ Increase economic growth
- ✓ Create new jobs
- ✓ Improve adoption of AM
- ✓ Enable exploitation of AM medical implants

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THANK YOU!

ENCOMPASS
DIGITAL INTEGRATED DESIGN DECISION SUPPORT SYSTEM

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PHOTONICS21 FoF