Development of Algorithms for generating connected midsurface using feature information in thin-walled parts

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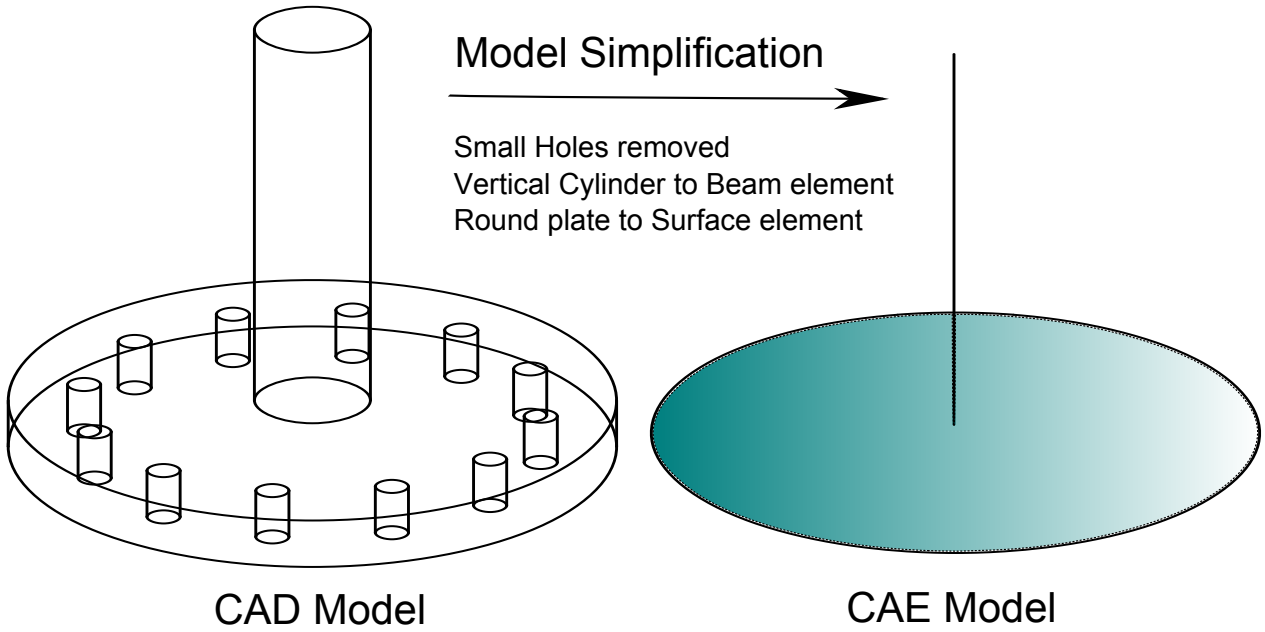
Agenda

Context

- Product Development: A quicker validation is crucial; fierce competition; faster obsolescence.
- Trend: Digital instead of Physical prototyping
- Meaning: Modeling by CAD and analysis by CAE
- How: More robust, quicker the CAD-CAE transition, faster is the product development, and design iterations
- Solution: Use of 'Model Simplification', De-featuring and Dimension Reduction.
- In the age of scalable and near-infinite computing power, for more design iterations quickly.

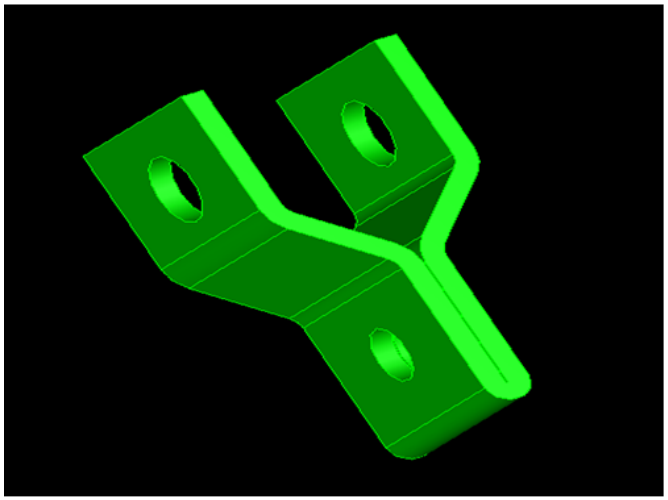
Specific solution

- Domain:'thin-walled models' i.e. Sheet Metal, Plastics etc
- Expensive 3D elements, 2D elements on midsurface
- Fairly accurate results in lesser computations/time.

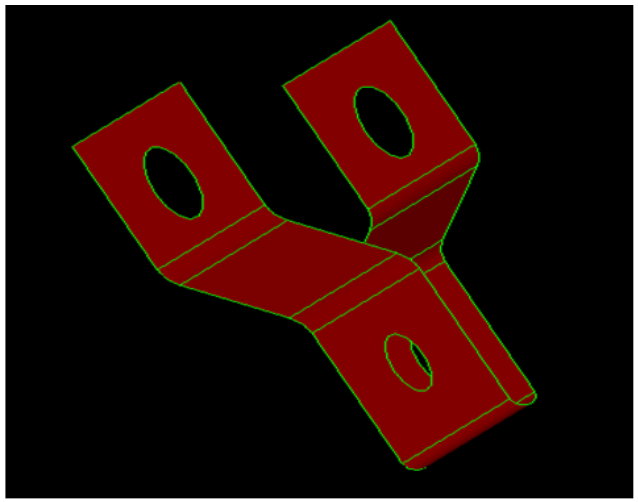


What is Midsurface?

- A surface lying midway of a thin-walled solid, mimicking its shape.
- Surface representation/idealization/abstraction along with thickness data
- Not expected to work for thick models



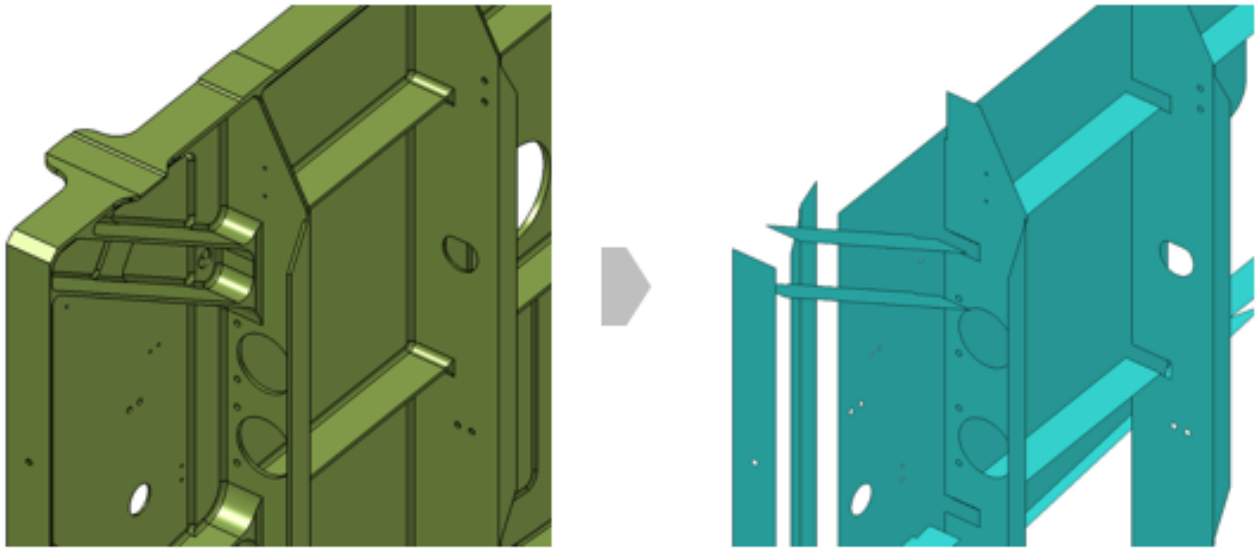
Input: Solid



Output: Midsurface

What is the problem?

- Gaps, Missing patches, Not lying midway



- Automated and robust technique is a crucial need

Research Potential

- Widely used but not robust
- Uses final Brep (due to legacy) and not features
- Research is still going on...(July 2015)

International Journal of Computer Integrated Manufacturing

CrossMark click for updates

Original Articles

Mid-surface abstraction for complex thin-wall models based on virtual decomposition

DOI: 10.1080/0951192X.2015.1068455

Huawei Zhu[a], Yanli Shao[a], Yusheng Liu[a*] & Chunguang Li[b]

Publishing models and article dates explained

Received: 31 Dec 2014
Accepted: 29 Jun 2015
Published online: 20 Jul 2015

Preview
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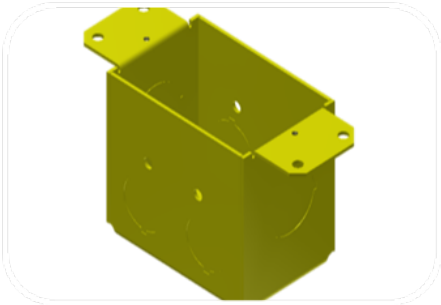
PDF
Access options

Where do you find Thin Wall models?

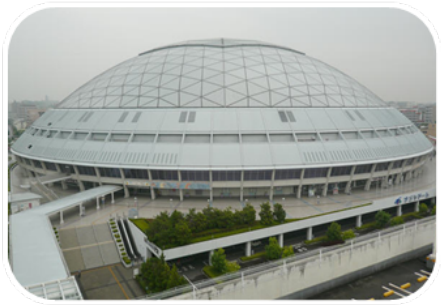
Aerospace



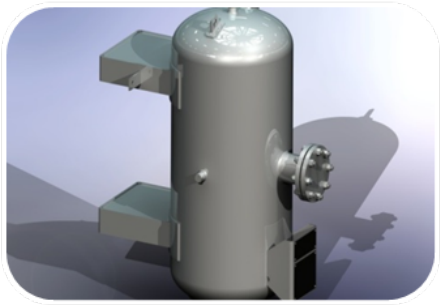
Machinery

Consumer Products

Energy



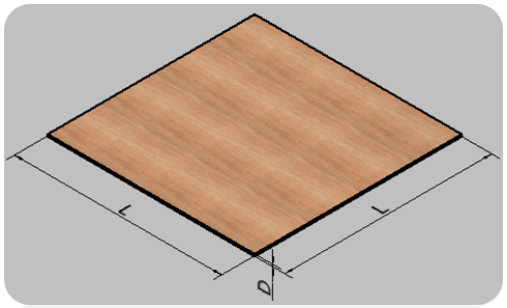
Construction



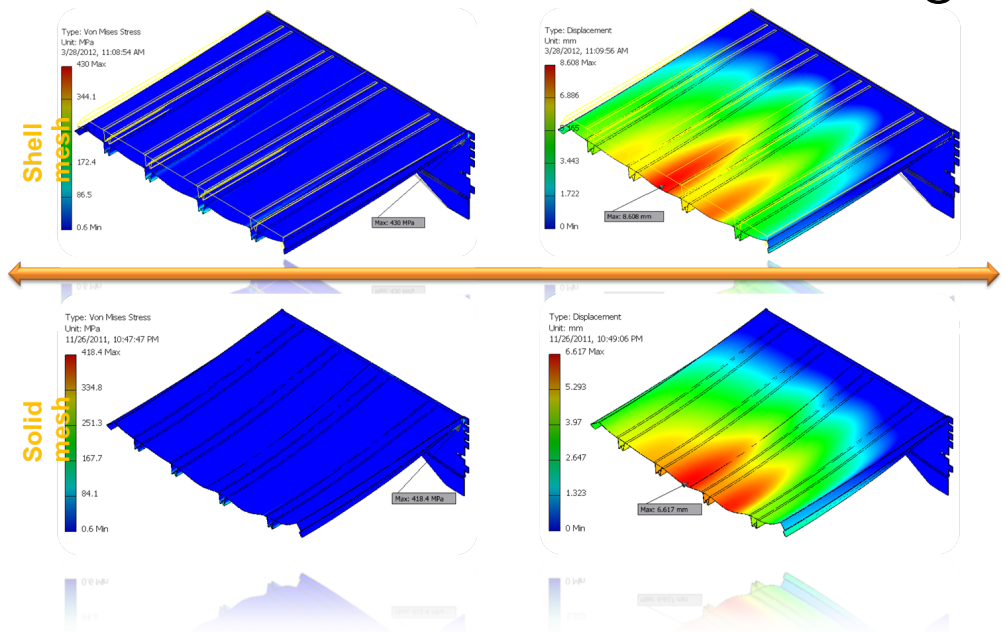
Industrial equipment

What is considered as **Thin**?

It is defined as a part or body with large effective span to thickness ratio (L/T)



For 'Thin', Solid and Shell elements give comparable results

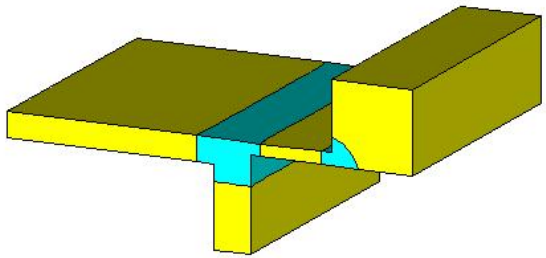


Classification of Thin-ness

Thickness threshold is based on the Length to Thickness ratio L/T

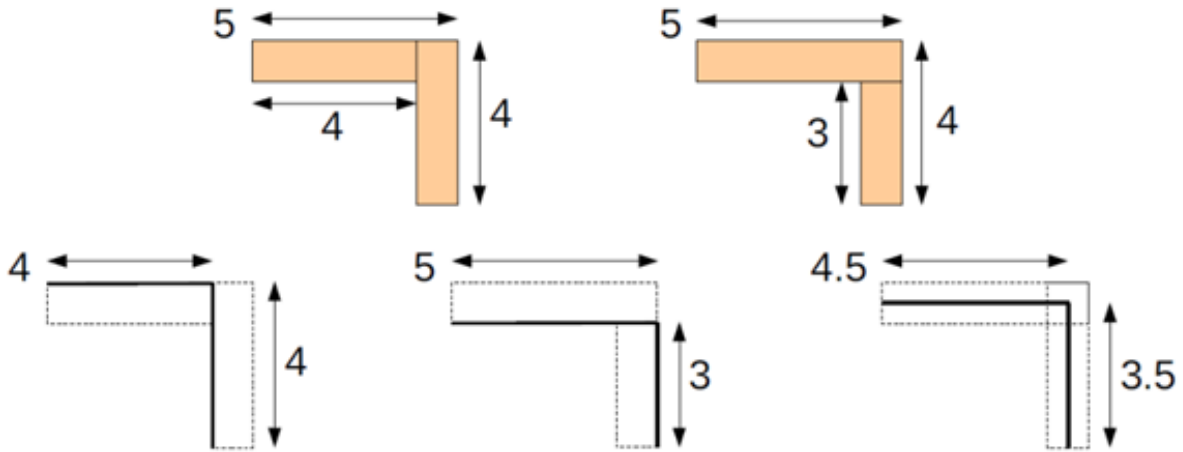
- Length = Overall length of the input solid body
- Thickness = Thickness of the input solid body

L/T **ratio**	**Interpretation**	**Element**
$L/T < 100$	Body is thick	Solid
$L/T \geq 100$ & $L/T \leq 250$	Body may be thin	Shell or Solid
$L/T > 250$ & $L/T \leq 750$	Body is thin	Shell
$L/T > 750$	Body is too thin	Certainly Shell



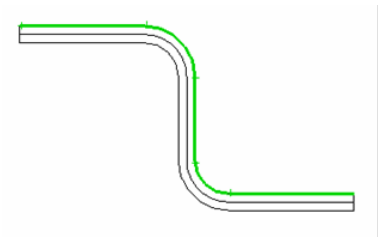
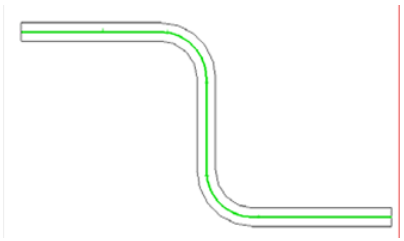
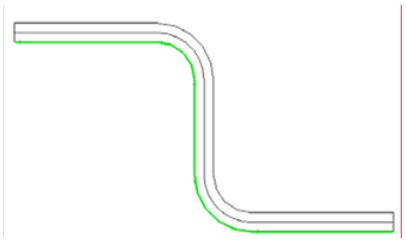
But why not just one side of it?

- Midsurface is needed to follow shape of the base part as well as carry thickness information. It should not be biased towards one of the sides.
- Figure shows two configurations for 'L' shape. Irrespective of the way they have been joined, CAE would like to have surface that would follow the base part shape and look like proper 'L'. If any of the sides are taken, results are skewed.



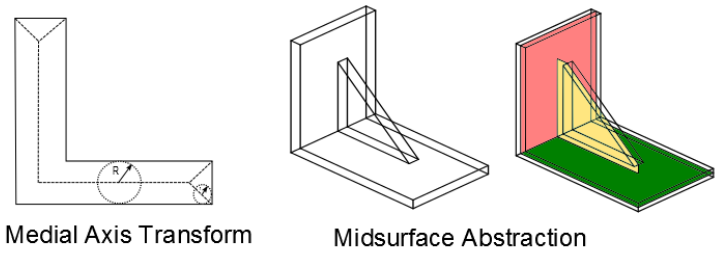
Effect of Thickness on Side-ness

- Shell elements are meshed on surfaces (compared to solids in volumes)
- COSMOS [SolidWorks] understands the shell placement to ALWAYS be at the Midsurface of the part
  - For convenience, it may be easier to choose an inside or outside part surface
  - The higher the part aspect ratio, the less it matters

Methods for Midsurface computation

- Midsurface Abstraction (MA) Approach and Medial Axis Transform (MAT) Approach are based on Extraction, meaning the algorithm is applied on the ready-final model to extract Midsurface.



- Many a times due to complexity in recognizing forms, their interactions, same design-intent used while modeling part can not be applied to Midsurface and thus Midsurface of part does not follow its form and connectivity
- Idea is to leverage the design intent in the form of feature history tree, to build the Midsurface as the way model gets built, step by step.

Agenda

Proposed Methodology

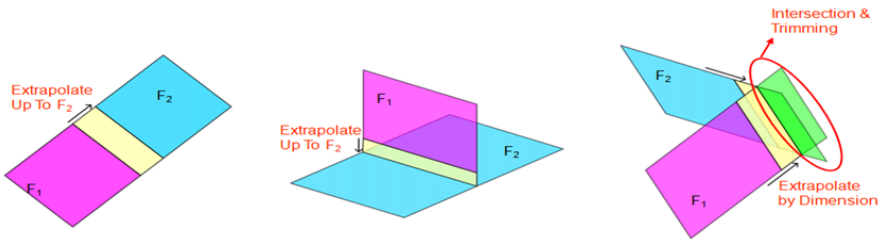
- To concurrently build mid-surfaces as part gets created (called forward create).
- At each feature step, shapes are relatively simple than final shape, thus creation of mid-surfaces at each stage is far simpler
- For each feature, decide its contribution to Midsurface model
  - 2D Profiles , generate Midcurves
  - Primitives, generate predefined Midsurfaces
  - Sweep based : Sweep Midcurves
  - Boolean : Extend and Trim

What is so special about Feature Tree

- Feature based Modeling is a powerful paradigm compared to modeling shapes by mesh or faces.
- Feature is a geometrical shape characterized by attributes relevant to the domains
- Part construction is stored as a sequence of features, in form of a Tree.
- Parametric nature of the Features and Update mechanism, give powerful editing capabilities.
- Most contemporary CAD packages use this to build and update models.

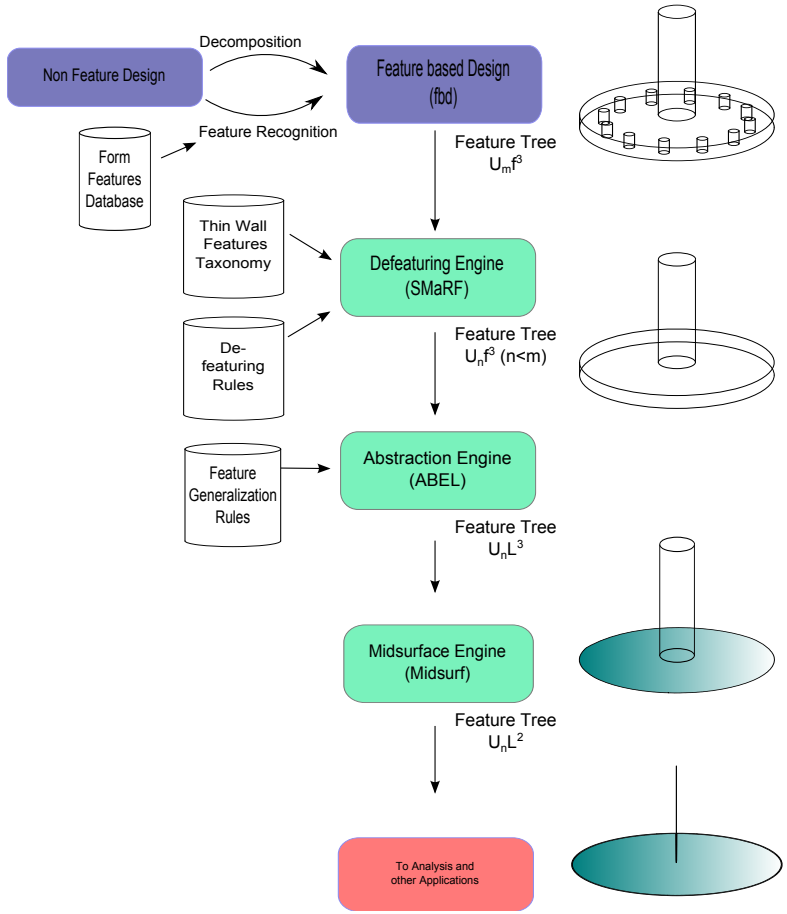
Proposal

- To concurrently build mid-surfaces as part gets created (called forward create).
- At each feature step, shapes are relatively simple than final shape, thus creation of mid-surfaces at each stage is far simpler.
- After development of Boolean of non-manifold shapes, this method can build well connected, isomorphic mid-surfaces better than reverse engineer way, which is currently followed.



Overall Approach

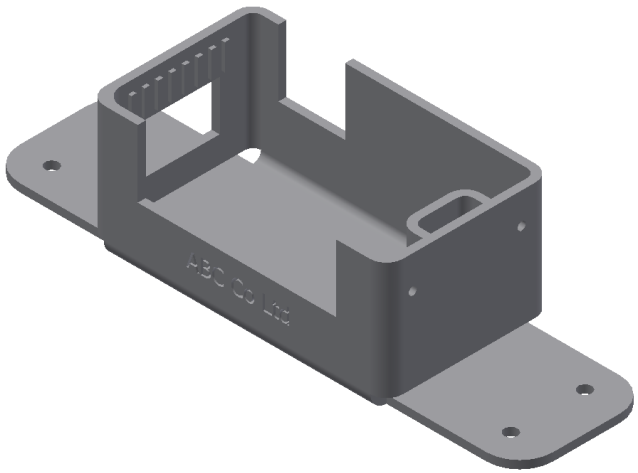
- De-featuring will suppress irrelevant features
- For each feature, decide its contribution to Midsurface model
  - 2D Profiles , generate Midcurves
  - Primitives, generate predefined Midsurfaces
  - Sweep based : Sweep Midcurves
  - Boolean : Extend and Trim



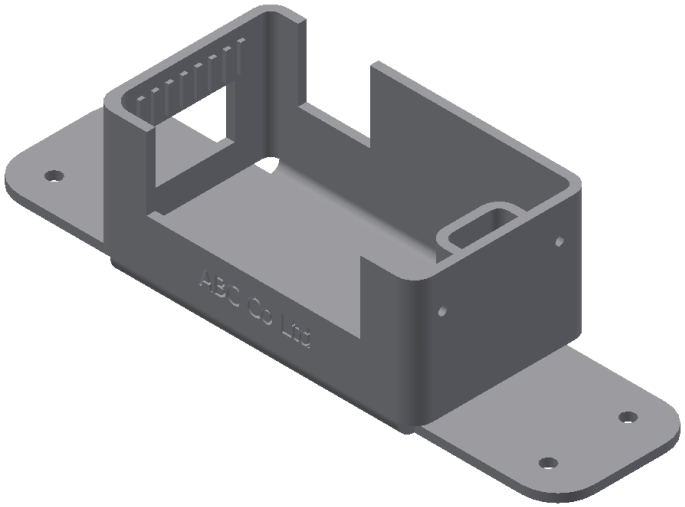
Agenda

Testing

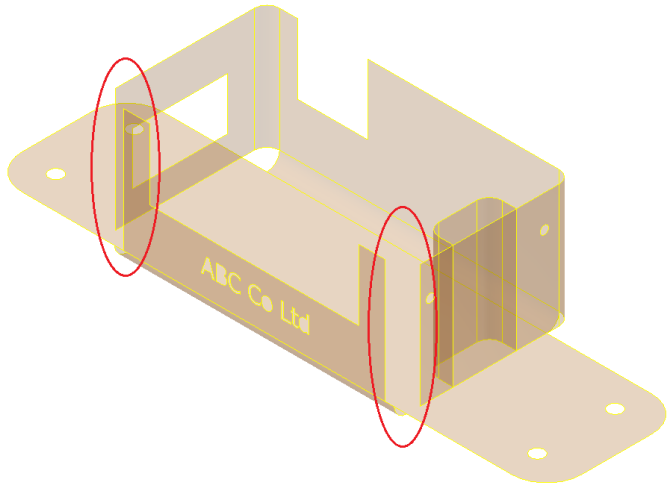
- Objective: To test and assess
- Academic models for simplicity in explanations
- Module specific models
- Real life part: “Enclosure”
  - Outer casing, two flaps with holes for screw fitments.
  - Slots for interfaces to external environment.
  - Embossed name. chute, slots for guiding wires in place.



Benchmarking Midsurface



(A) Input Part

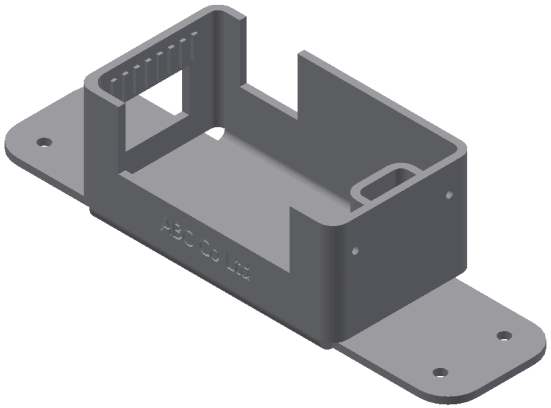
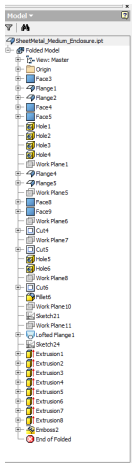


(B) Commercial Application

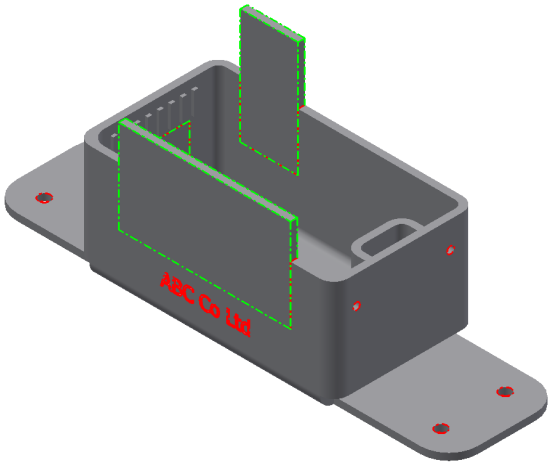
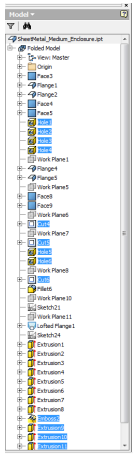
Quite a few failures are seen, such as disconnected patches, missing midsurface patches etc.

Simplification

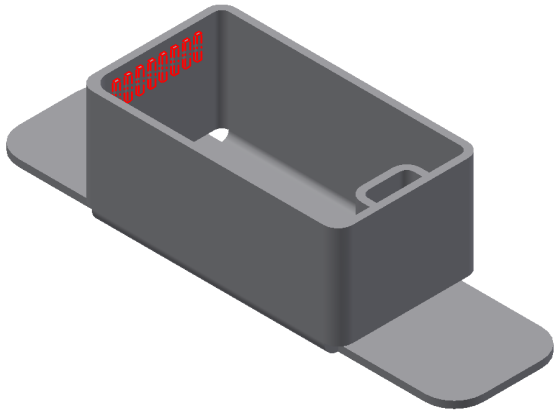
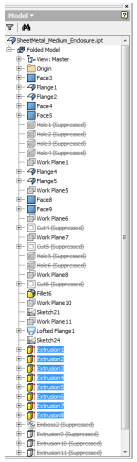
- Removes unwanted features to compute the “gross shape”.
- Caches tool-bodies of non-suppressible negative features to be used for piercing after midsurface computation.

Model		Tree	Explanation
Original/Input			Input with Sheet Metal features.

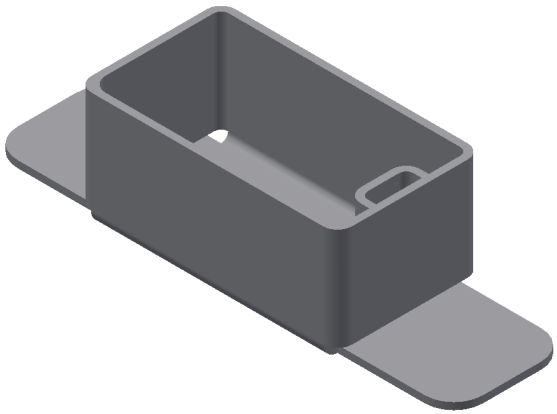
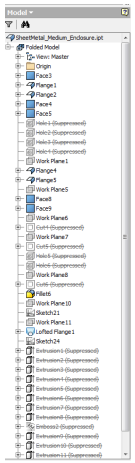
Phase I

	Model	Tree	Explanation
Phase I Selections			Small holes, embossing is chosen based on Sheet Metal feature taxonomy rules (shown red). The green selections are the dormant feature bodies cached.

Phase II

	Model	Tree	Explanation
Phase II Selections			Remnant features got selected in the second phase.

Output

	Model	Tree	Explanation
Defeatured			Most of the unnecessary features are removed and now it retains all the necessary features adequately "representing" the gross shape.

Effectiveness

Effectiveness with 5% threshold, based on the criterion defined is:

Qty	Input	Phase I	Output
Faces	259	104	64
Suppressed		13	8

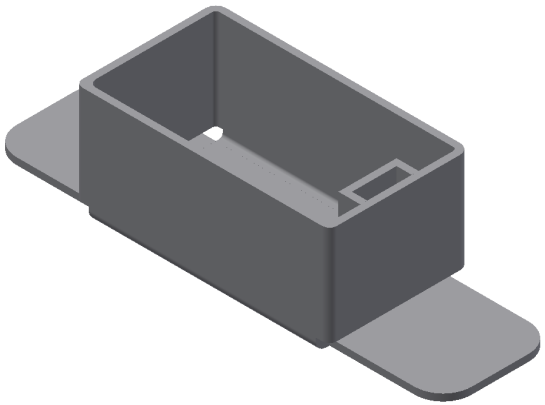
$$pR = (1 - \frac{64}{259}) \times 100 = 75.29\%$$

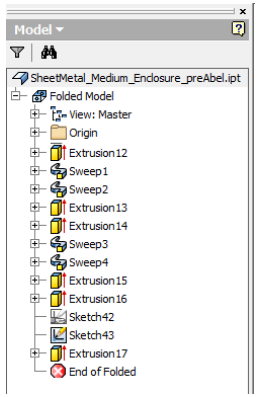
Even after huge reduction in the number of faces (75%), the overall shape of the enclosure is retained fine.

Abstraction

- To transform sheet metal feature tree into $\mathcal{ABLE}$ feature (Extrude, Revolve, Sweep, Loft) tree.
- Effectiveness is in the faithful reproduction of the part, without any feature or shape loss.

Abstracted Output



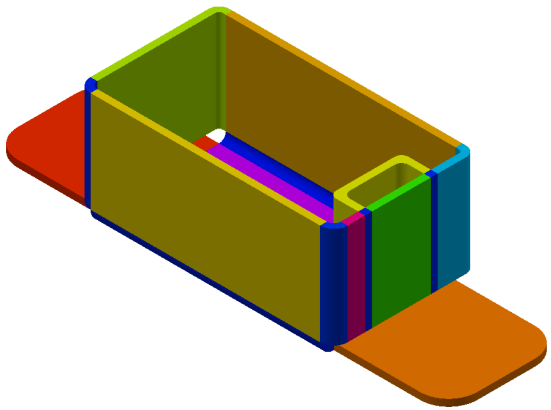


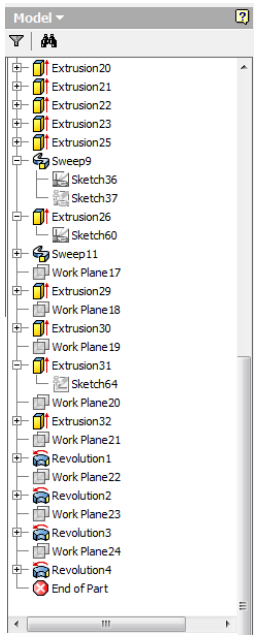
All Sheet Metal features are abstracted/-converted to basic primitive features such as Extrude, Sweep etc.

Decomposition

- Decomposition is a manual process.
- Feature partitioning: Internal as well as external booleans are changed to the "New Body"
- Concave edge partitioning: Overlapping volumes are split at concave edges.

Decomposed Output

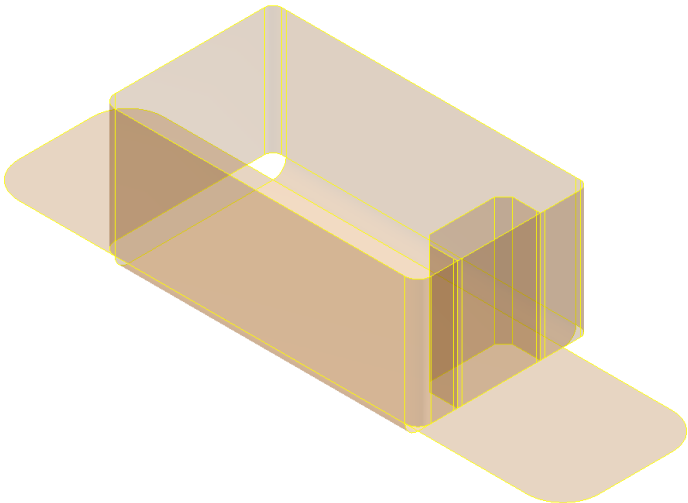




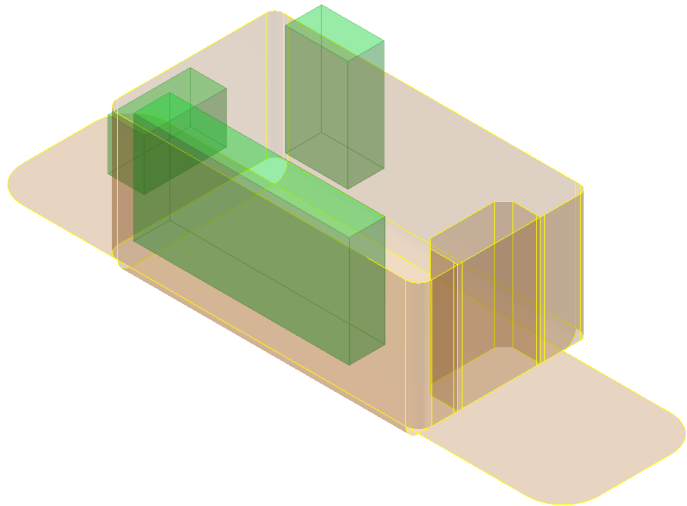
List of sub-voumnes/cells with a primitive/$\mathcal{ABLE}$ owner feature assigned.

Computation

- Midsurface patches and connections are computed
- Dormant bodies cached during defeaturing module are brought back to pierce into this midsurface, so as to generate the pending cuts.

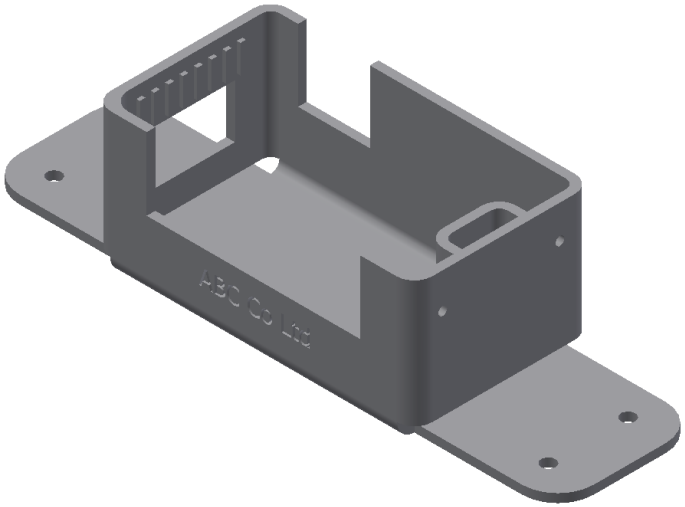


(C) Original Part

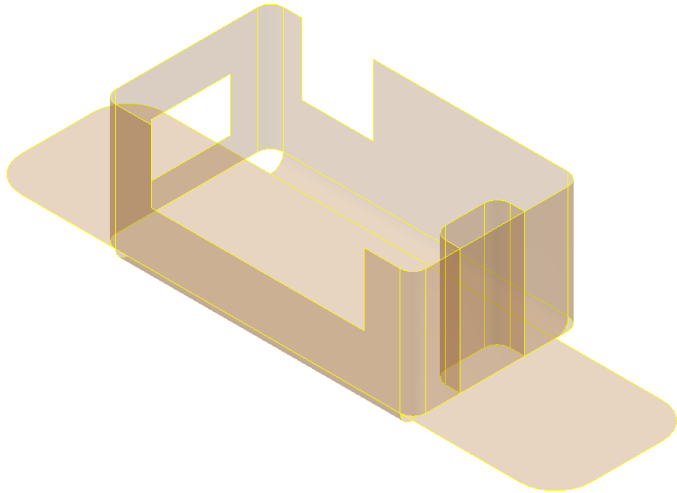


(D) Dormant Piercing

Final Midsurface



(E) Original Part



(F) This Research

Agenda

Conclusion

- Although Model Simplification using geometry has been in practice for many years, with possibility of extracting feature information, it can be taken to the next level.
- Feature information gives ready data needed for Model Simplification. Features such as Pattern leverage the symmetry in the part thereby reducing analysis time-resources.
- In Dimension Reduction, it can give tips for creating medial geometries.
- In the proposed approach Midsurface is concurrently built as part gets created (called forward create). At each feature step, shapes are relatively simple than final shape, thus creation of mid-surfaces at each stage is far simpler.
- This approach can build well connected, isomorphic mid-surfaces better than extraction methods.

Agenda

Papers: Current Status

- Feature based midsurface (Overall):

  ICAME-CoEP-2013 (Intl Conf - published)
  GMP-2015 (submitted)

- Model Simplification, De-featuring:

  CAE-IITM-2013 (Intl Conf - published)
  CAD-London-2015 (Intl Conf - published)
  CADandA-2015 (Intl Jrnl - accepted)

- Abstraction: AIMTDR-IITg-2014 (Intl Conf - published)
- Midcurves (Algorithm):

  ETES-Asansol-2014 (Natl Conf - published)
  IJCAET-2017 (Intl Jrnl - accepted)

- Midsurface (Algorithm): Eng with Computers (submitted)
- Validation: CADandApplications (Intl Jrnl - published)

Agenda

References I

Thanks ... yogeshkulkarni@yahoo.com