AN APPROACH TO STUDY AND AVOID FAILURE OF PLASTIC ASSEMBLED PARTS USING MOLDLFOW

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Class summary

- Moldflow's excellent capability to evaluate "What if" scenarios before cutting tool
- Moldflow's capability to do failure analysis of parts failing during testing / actual usage
- Better approach to interpret results as individual part and its importance in assembly
- Moldflow's ability to assist project team for first time right part / molds

Key learning objectives

At the end of this class, you will be able to:

- Explain how part design changes influence part deflections
- Explain benefits of Moldflow, in early part design phase is beneficial
- Understand how best we can apply Moldflow to evaluate problems
- Explain one of the better approach of controlling the assembly failure of plastic parts.

Agenda

- TATA Technologies – Brief Overview
- Types of work we do!
- Use of Autodesk Moldflow
- Case study
  - Problem definition
  - Objective and deliverable
  - Other important information and key constraints
  - Our approach to tackle this problem
  - Work details on parts
  - Welding types
- Conclusion
- Q & A session

TATA Technologies- An overview

Overview

- TATA Technologies is the largest Indian pure play Engineering Services Outsourcing (ESO) provider*
- Its 7,600+ professionals represent the largest technical workforce dedicated to the offshoring of engineering services in the Automotive, Aerospace an Industrial machinery industry
- Tata Technologies essential value proposition is to be a technology partner to manufacturers globally, through process optimization, outsourcing of product development and application of Product Lifecycle Management (PLM) services

Business

- **Services**
  - Engineering and Design services
  - Product and information lifecycle management
  - Enterprise solutions & process automation tools
  - Value Added Reselling of Products

Footprint

- India, USA, UK, Canada, Germany, France, Japan, Mexico, Singapore, Korea and Thailand
- ISO & AS9100 certified delivery centers in Pune, Bangalore and Thailand

Customers

Key Metrics

- $400 Million in Revenue (FY'13)
- Over 7,600 employees helping 2000 clients
- Operations in 15 Countries
- Works with all the top ten aerospace OEMs
- Works with all the top ten automotive OEMs

** As per Booz & Company Study*

TATA Technologies - Global Delivery Centers

–Operations in 15 Countries

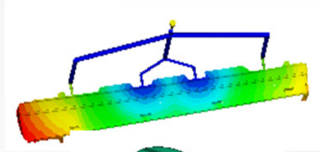
- TATA Technologies and Cambric's combined capacity puts us ahead of every other service provider in the market
- Expanded global footprint matching our Customer footprint
- Complementary Capabilities & Operations

Types of work we do!

Flow Analysis

<u>It Gives</u>:

- Uniformity of fill
- Gate dimension and location
- Weld line locations
- Gas / Air entrapments
- Pressure and temperature optimization
- Filling Sequence of nozzles
- Mold / part balancing



Thermal with STRESS Analysis (STUDY PART as advanced CAE)

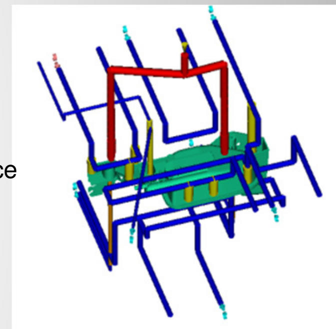
- Mechanical property, finite element mesh, and residual stress data
 can be easily transferred from Moldflow to Abacus, ANSYS,
 LSDYNA, NASTRAN
- The inclusion of residual processing stresses in an Abacus - analysis allows for more accurate simulation of the injection molded product.

INJECTION MOLDING PROECESS CAE

COOL Analysis

<u>It Gives</u>: -

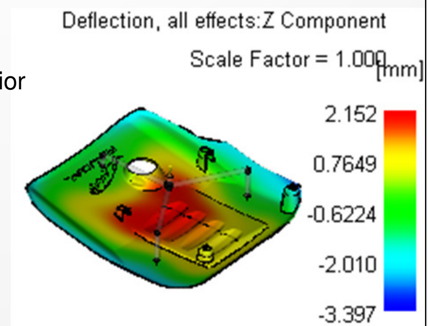
- Time to reach ejection temperature
- Hot spot locations
- Coolant efficiency
- Circuit coolant temperature difference
- Time to freeze feed system
- Hot spot locations
- Coolant efficiency



WARP Analysis

<u>It Gives</u>:

- Deflection in terms of magnitude and behavior
- Deflection directions
- Deflection due to shrinkage
- Deflection due to orientation
- Deflection due to corner effect
- Deflection due to differential cooling



Use / Benefits of carrying out Moldlfow analysis

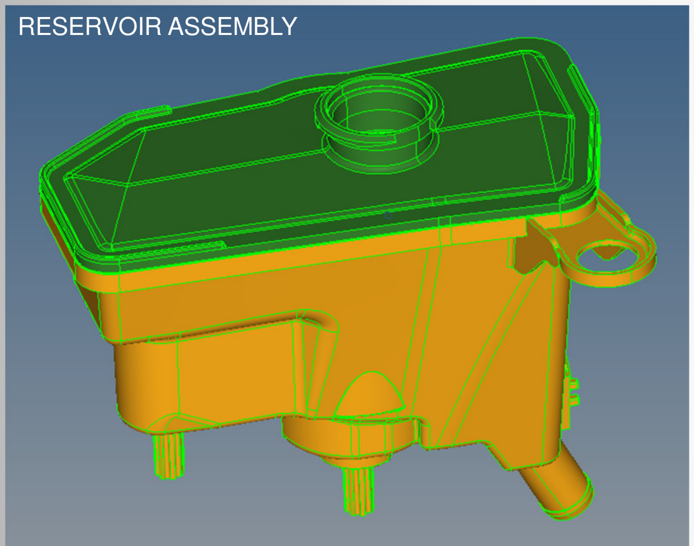
- MOLDFLOW analysis helps:
  - Reduce costly physical prototypes
  - Avoid potential manufacturing defects
  - Give RIGHT inputs to tool maker at RIGHT time
  - Flexibility to product designer at initial stages
  - Give optimized Process parameters to manufacturing
  - Many more…

- MOLDFLOW can be used :
  - During product design stages (Recommended)
  - To do failure analysis of plastic part

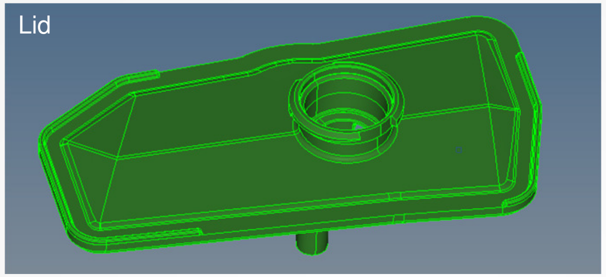
Our Case-study, in this presentation is about to study the failure analysis of one of our project.

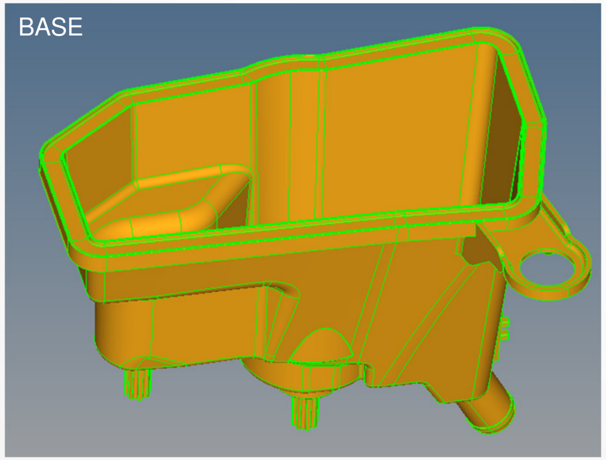
CASE STUDY : Problem definition

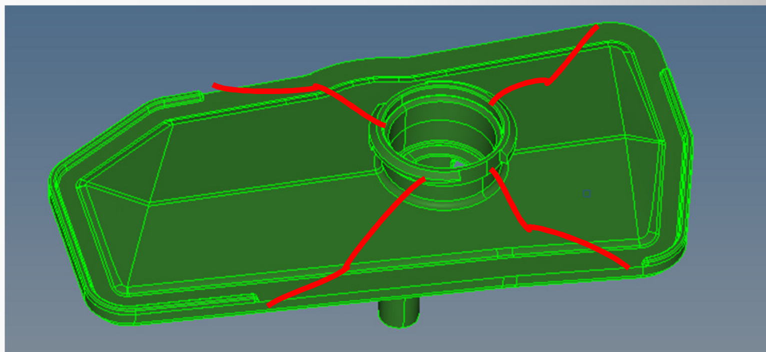
Objective of Moldflow study:
Identification of issues and develop methodology to troubleshoot failure of welded plastic assemblies



LID & BASE part to be vibration welded.







PART BREAKING FROM CENTER,DURING TESTING

Deliverables:
- Suggest solutions in current scenario
- Develop methodology to control failure of welded assemblies

CASE STUDY : Key information

Other important information about part:

Material of Lid and Base:

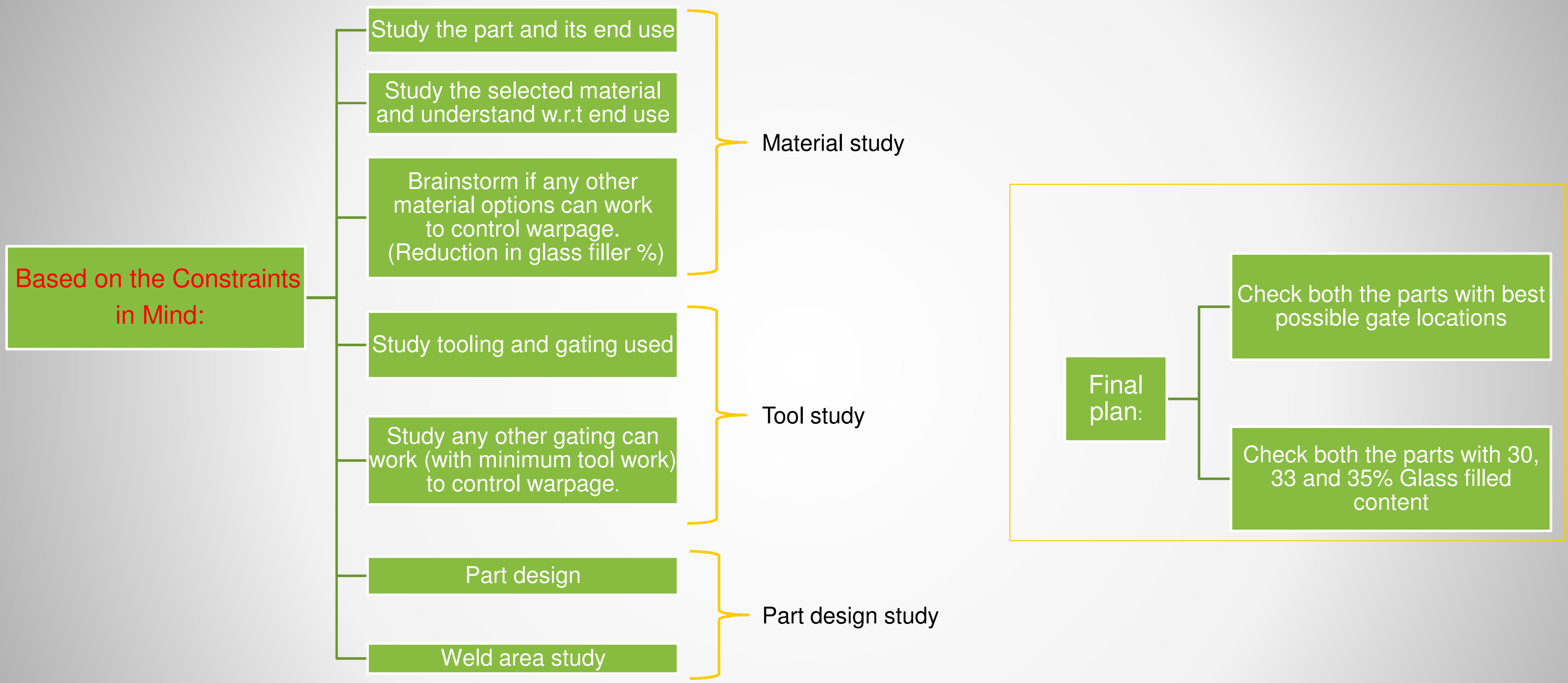
- Polyamide 66
- Heat stabilized
- 35% glass filled
- Injection molding grade
- This grade is commonly used in the automotive industry for engine components, such as: inlet manifolds, air ducts, engine cover and various housings and liquid containers

Key Points & Constraints: ☺ / ☹

- Lid part was breaking in 2-4 pieces during testing.
- Injection molds for both the parts were ready; very little scope for major tool modifications.
- Suggestion of tool modification should be simple and easy to accommodate in current tool.
- Need to maintain the FALTNESS to ease welding
- No change in material permitted due to shrinkage factor considered while cutting the tool.

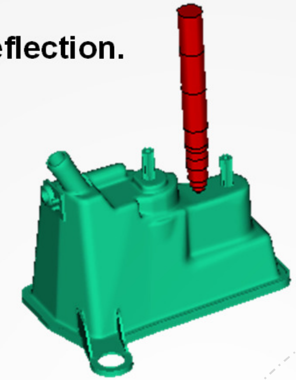
(Only option thought to play with % of glass fillers (30,33,35%) from same material supplier to check the effect).

CASE STUDY : Approach

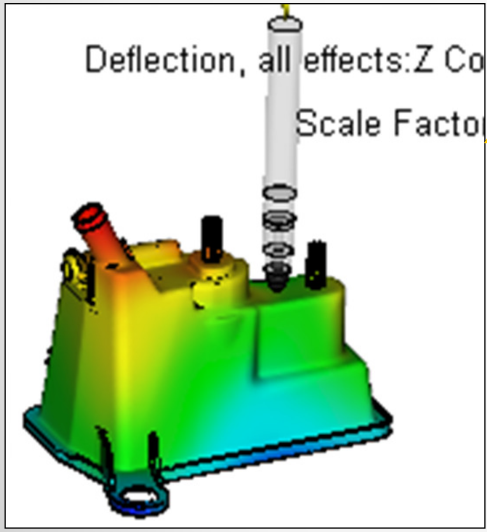


CASE STUDY : Base Part

- For Base part we sticked to same current gate location as we had observed less deflection (Flange/ weld area) ~0.1-0.6mm
- Just checked the effect of glass fiber % variation on deflection.

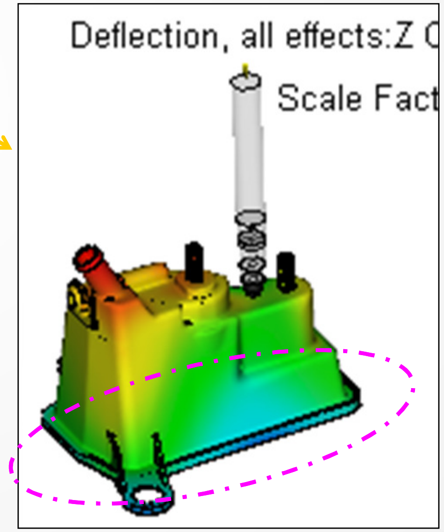


PA66-GF 30%



Overall Deflection was around 1 mm

PA66-GF 35%



Overall Deflection around flange was around 0.5mm

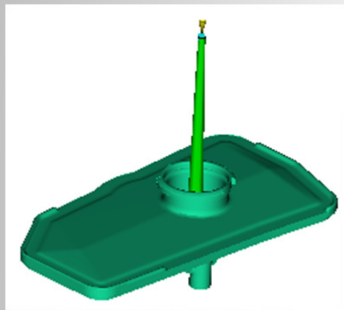
Freeze this case & went ahead for LID part

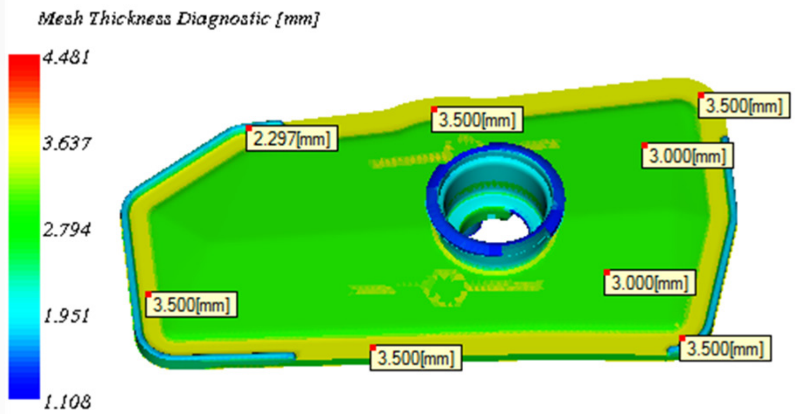
CASE STUDY : Lid Part

More deflection in physical part (~ 2-3 mm); Key task for us to study and reduce the deflection.

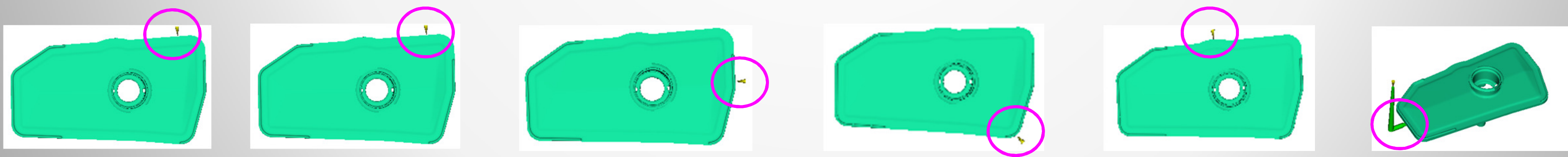
- **Checked various gate locations**
- **Various part design modifications**
- **Varied glass filler % material options**

Current Tool gating: 3-Submarine gate at center- with cold sprue





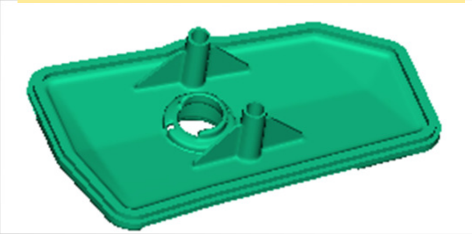
Various gate location, 30, 35 % PA66 GF tried to check the effect on deflection :



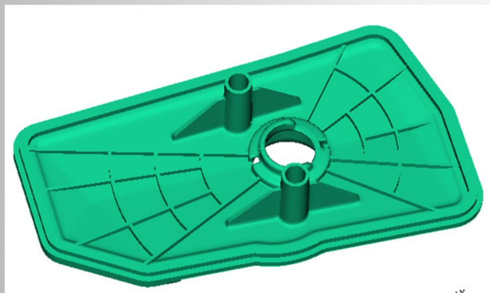
LID PART:

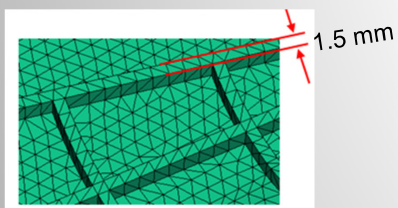
- **Needed more satisfactory results : Next plan was to work on part modifications**

NO RIBBING IN ORIGINAL DESIGN:



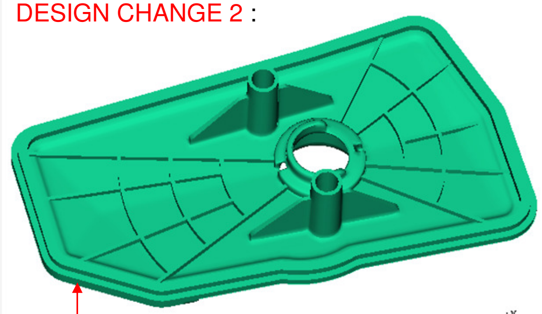
DESIGN CHANGE 1 :

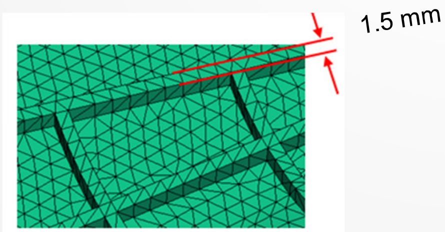




Rib height: 2.5mm

DESIGN CHANGE 2 :

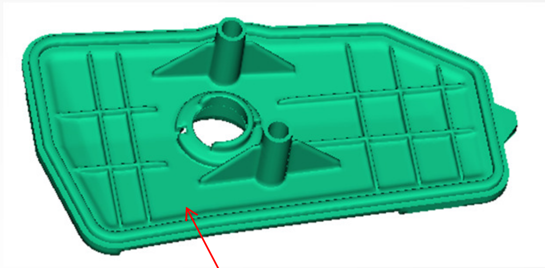




Rib height: 2.5mm

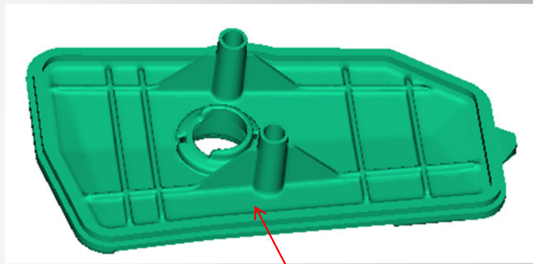
2. Flange thickness reduced to 3mm from 3.5 mm

DESIGN CHANGE 3 :



Flange thickness reduced to 3mm from 3.5 mm

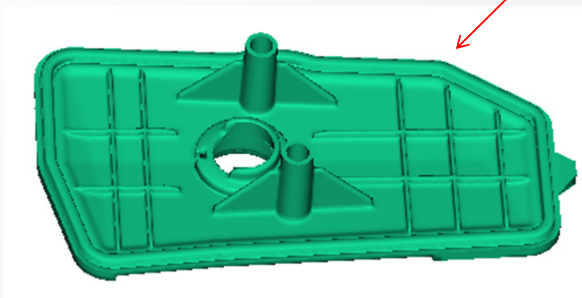
DESIGN CHANGE 4 :

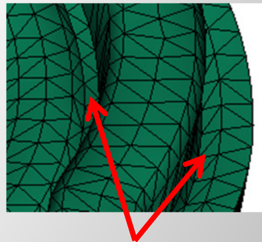


Flange thickness reduced to 3mm from 3.5 mm

DESIGN CHANGE 5 :

Flange thickness reduced to 3mm from 3.5 mm +notch



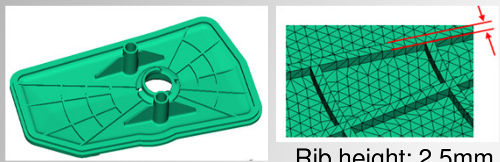


Local notched to reduce the thickness in flange:

LID PART:

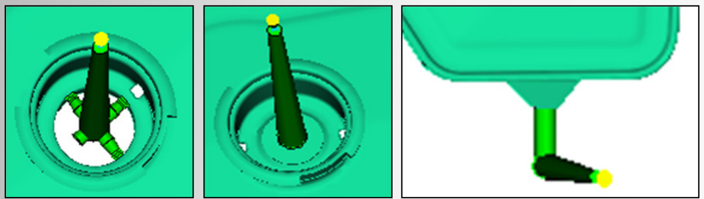
- **Design changes with various gate locations:**

DESIGN CHANGE 1 :



1.5 mm

Rib height: 2.5mm



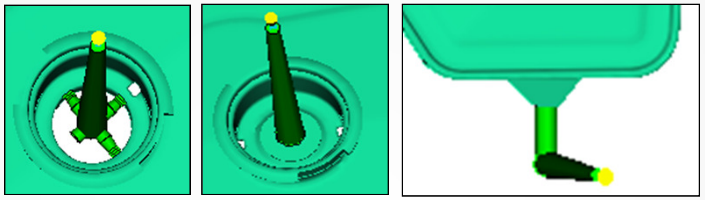
CASE-1: CASE-2: CASE-3:

DESIGN CHANGE 2 :

1.5 mm

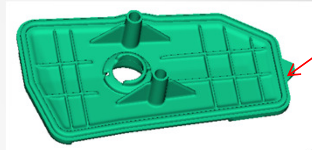
Rib height: 2.5mm

2. Flange thickness reduced to 3mm from 3.5 mm

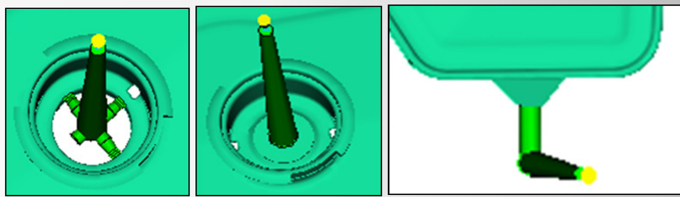


CASE-4: CASE-5: CASE-6:

DESIGN CHANGE 3 :



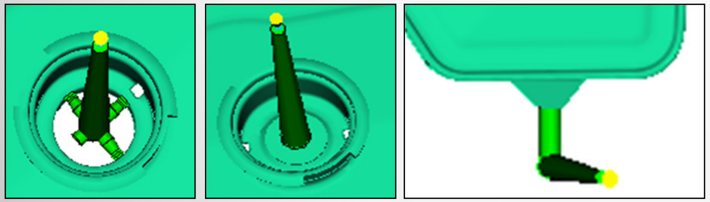
Flange thickness reduced to 3mm from 3.5 mm



CASE-7: CASE-8: CASE-9:

DESIGN CHANGE 4 :

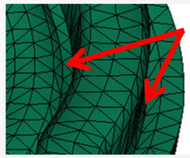
Flange thickness reduced to 3mm from 3.5 mm



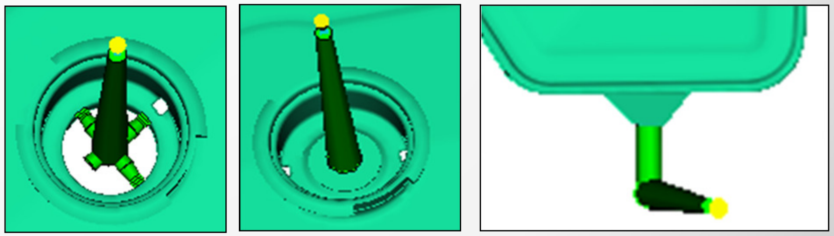
CASE-10: CASE-11: CASE-12:

DESIGN CHANGE 5 :

Flange thickness reduced to 3mm from 3.5 mm +notch



Local notched to reduce the thickness in flange:



CASE-13: CASE-14: CASE-15:

- **Imp result summary of last 15 Cases**

CASE STUDY		CASE-1 Edge Gate	CASE-2 Diaphragm Gate	CASE-3 Fan Gate	CASE-4 Edge Gate	CASE-5 Diaphragm Gate	CASE-6 Fan Gate
FT (Sec)		1.324	1.329	1.588	1.438	1.423	1.691
V/P P (MPa)		51.78	44.18	53.93	49.54	42.85	54.62
DFL (MM)	X	0.64 to -0.6	0.59 to -0.63	0.68 to -0.73	0.64 to -0.64	0.65 to -0.63	0.69 to -0.73
	Y	0.66 to -0.62	0.66 to -0.64	0.61 to -0.62	0.66 to -0.61	0.69 to -0.69	0.62 to - 0.68
	Z	1.3 to -0.65	1.32 to -0.70	1.54 to -0.81	1.34 to -0.70	1.30 to -0.71	1.43 to -0.84

CASE STUDY		CASE-7 Edge Gate	CASE-8 Diaphragm Gate	CASE-9 Fan gate	CASE-10 Edge Gate	CASE-11 Diaphragm Gate	CASE-12 Fan Gate
FT (Sec)		1.446	1.424	1.696	1.339	1.419	1.695
V/P P (MPa)		49.58	43.01	53.29	51.13	43.38	52.57
DFL (MM)	X	0.64 to -0.65	0.68 to -0.62	0.69 to -0.74	0.63 to -0.68	0.65 to -0.62	0.69 to -0.76
	Y	0.66 to -0.62	0.74 to -0.69	0.61 to -0.66	0.63 to -0.57	0.66 to -0.66	0.6 to -0.61
	Z	1.38 to -0.69	1.42 to -0.83	1.38 to -0.80	1.26 to -0.66	1.22 to -0.68	1.37 to -0.81

CASE STUDY		CASE-13 Edge gate	CASE-14 Diaphragm Gate	CASE-15 Fan Gate
FT (Sec)		1.438	1.426	1.691
V/P P (MPa)		49.60	43.40	52.32
DFL (MM)	X	0.64 to -0.68	0.72 to -0.66	0.69 to -0.77
	Y	0.64 to -0.58	0.71 to -0.71	0.59 to -0.59
	Z	1.08 to -0.66	1.27 to -0.77	1.25 to -0.77

- **Imp result summary of last 15 Cases**

CASE STUDY		CASE-1 Edge Gate	CASE-2 Diaphragm Gate	CASE-3 Fan Gate	CASE-4 Edge Gate	CASE-5 Diaphragm Gate	CASE-6 Fan Gate
FT (Sec)		1.324	1.329	1.588	1.438	1.423	1.691
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DFL (MM)	X	0.64 to -0.6	0.59 to -0.63	0.68 to -0.73	0.64 to -0.64	0.65 to -0.63	0.69 to -0.73
	Y	0.66 to -0.62	0.66 to -0.64	0.61 to -0.62	0.66 to -0.61	0.69 to -0.69	0.62 to - 0.68
	Z	1.3 to -0.65	1.32 to -0.70	1.54 to -0.81	1.34 to -0.70	1.30 to -0.71	1.43 to -0.84

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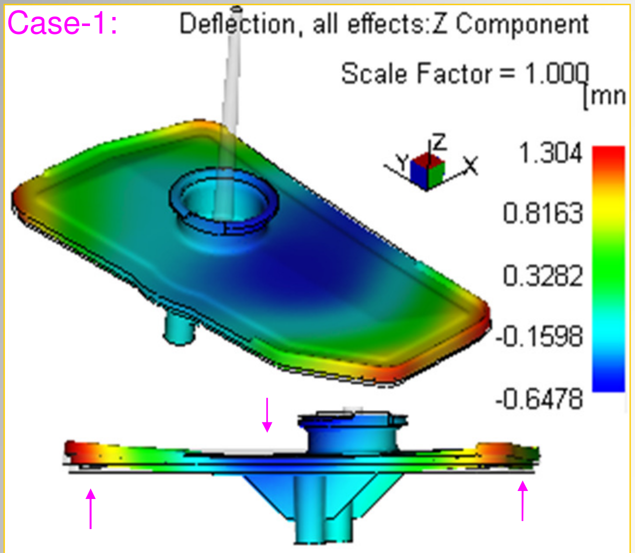
	Y	0.66 to -0.62	0.74 to -0.69	0.61 to -0.66	0.63 to -0.57	0.66 to -0.66	0.6 to -0.61
	Z	1.38 to -0.69	1.42 to -0.83	1.38 to -0.80	1.26 to -0.66	1.22 to -0.68	1.37 to -0.81

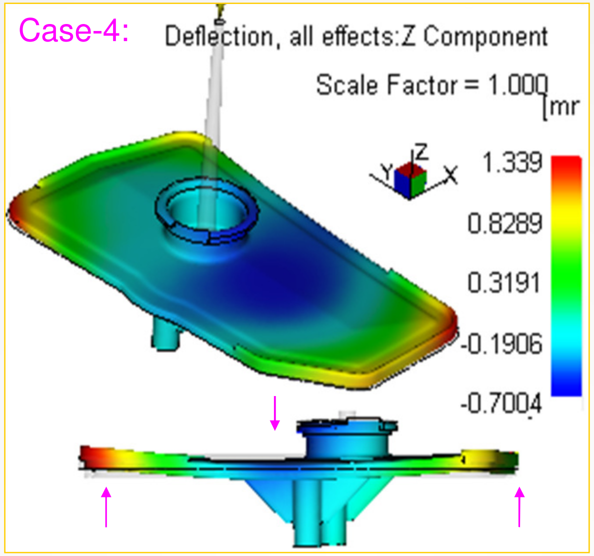
CASE STUDY		CASE-13 Edge gate	CASE-14 Diaphragm Gate	CASE-15 Fan Gate
FT (Sec)		1.438	1.426	1.691
V/P P (MPa)		49.60	43.40	52.32
DFL (MM)	X	0.64 to -0.68	0.72 to -0.66	0.69 to -0.77
	Y	0.64 to -0.58	0.71 to -0.71	0.59 to -0.59
	Z	1.08 to -0.66	1.27 to -0.77	1.25 to -0.77

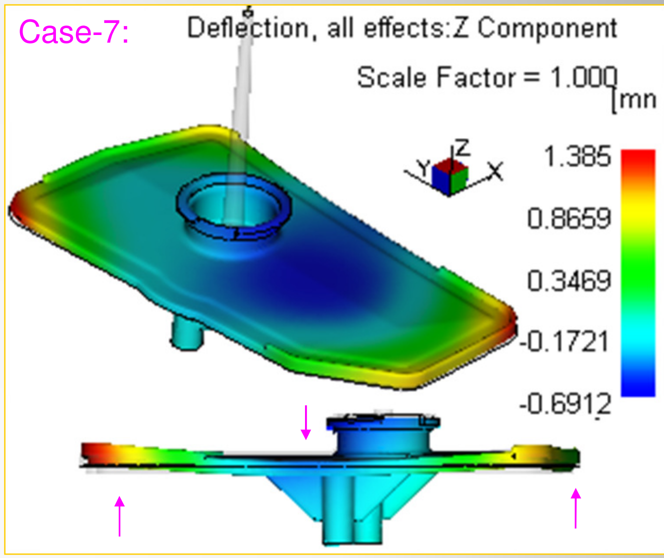
Conclusion at this stage:

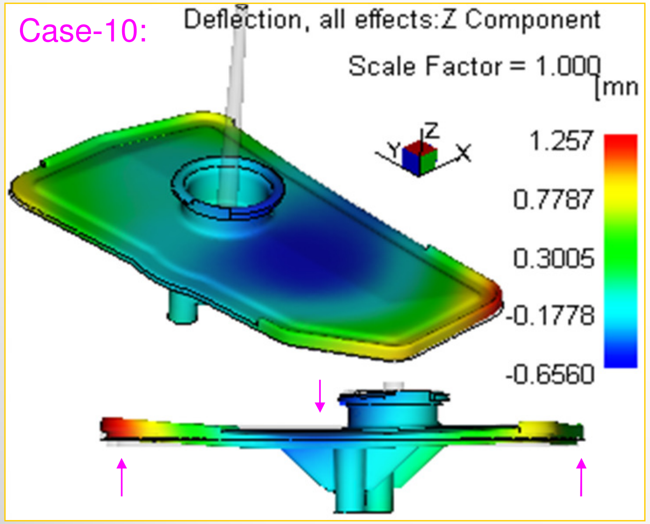
Here we have understood some trend and we shortlisted 5 CASES based on our initial constraints (being tool was made)

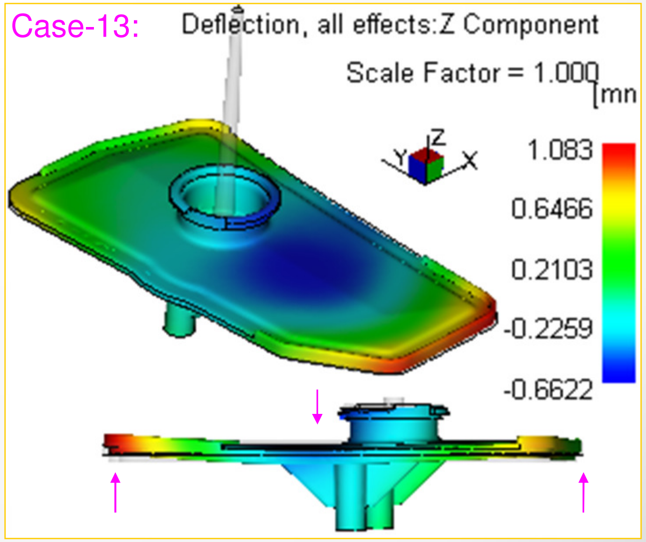
- **Deflection results:**



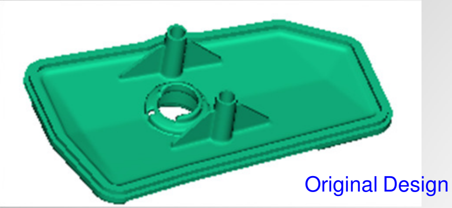


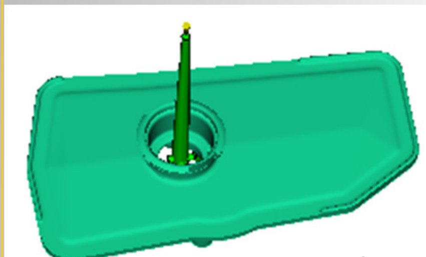




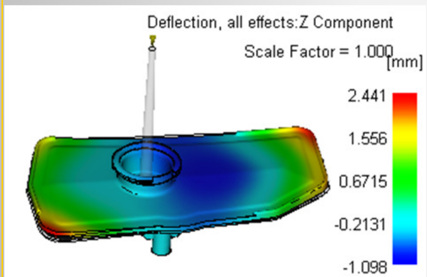


- Coming to the conclusion:

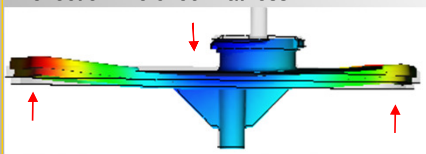




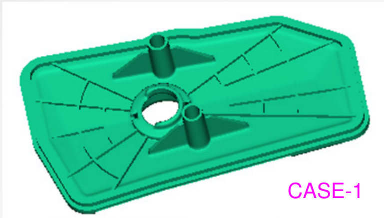
Feed System in tool

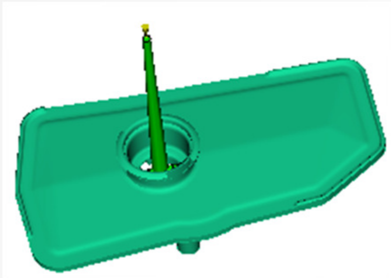


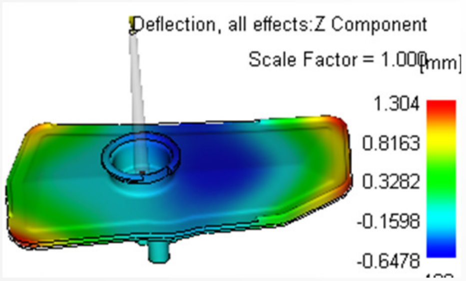
Deflection: To check flatness



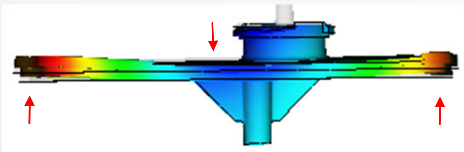
Part is twisting & bowing for this part design with current gate location



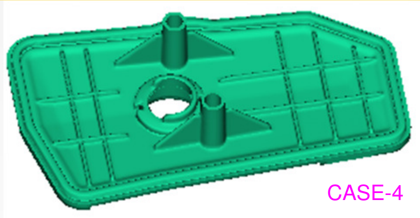


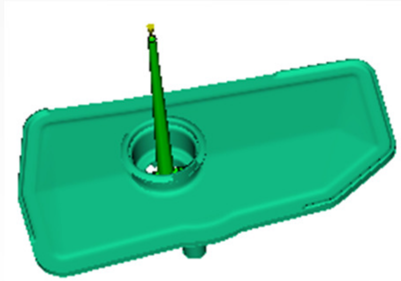


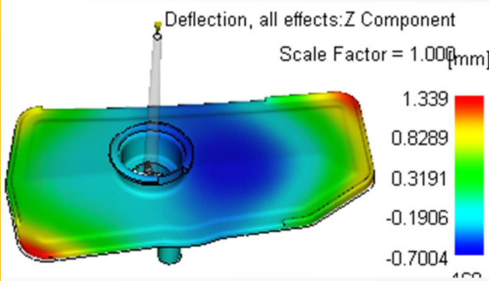
Deflection: To check flatness

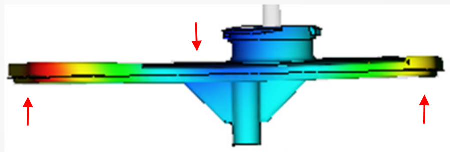


Deflection reduced with rib addition and - Twisting reduced

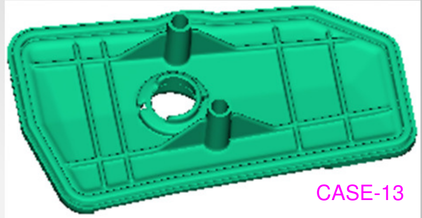


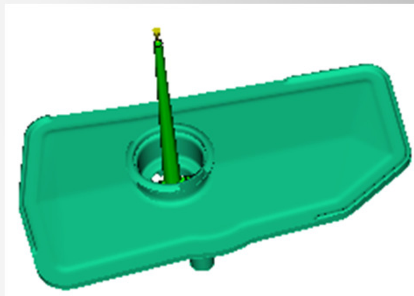


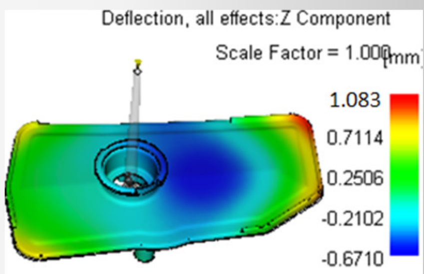


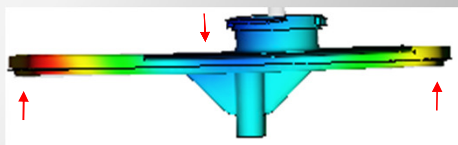


Deflection reduced with rib addition Twisting increased for this rib design







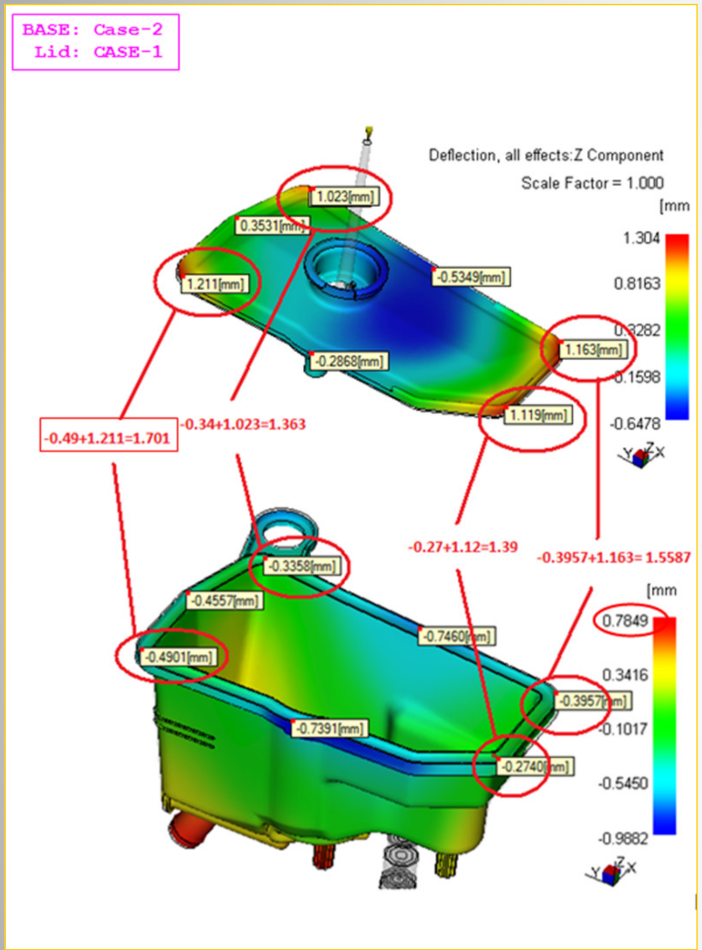


Deflection reduced further with less twisting and bowing

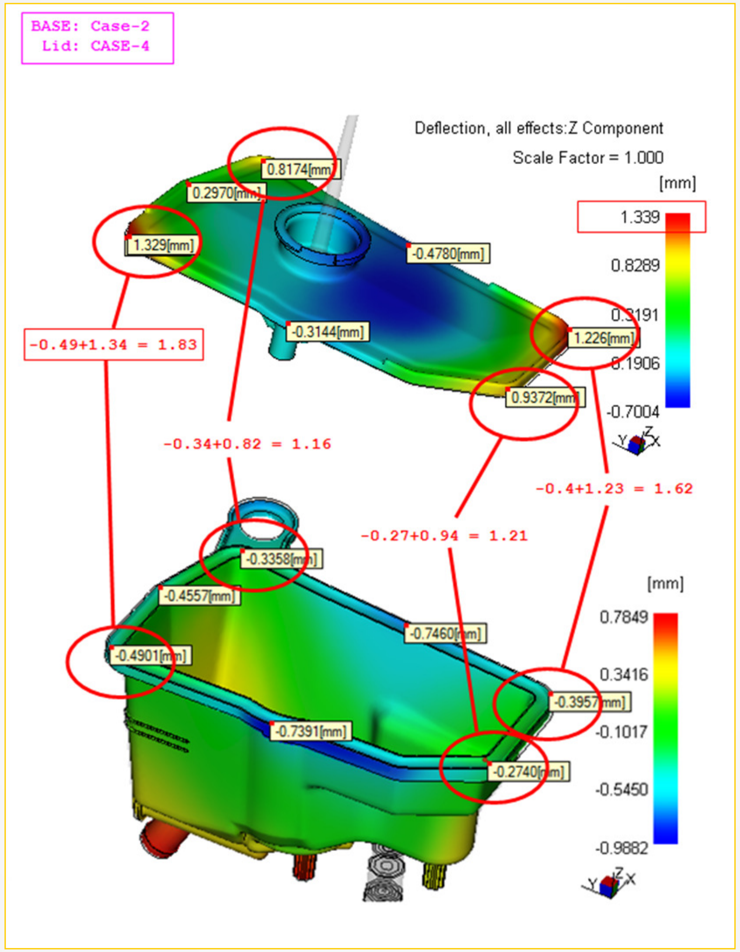
- **Now we knew how both the parts were behaving for various materials and gate design and types.**

- **Most interesting part is the next step : To study the assembly level deflection for the shortlisted case i.e. to study the FLATNESS for ease of welding!**

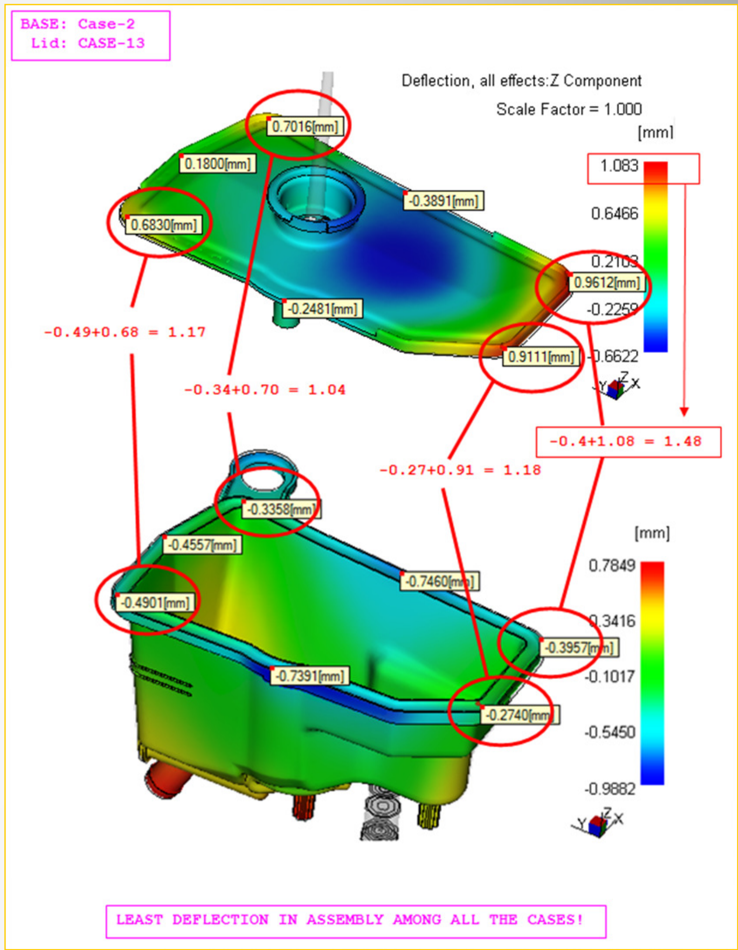
- Assembly level deflection study of both the parts



Assembly level deflection=1.7mm



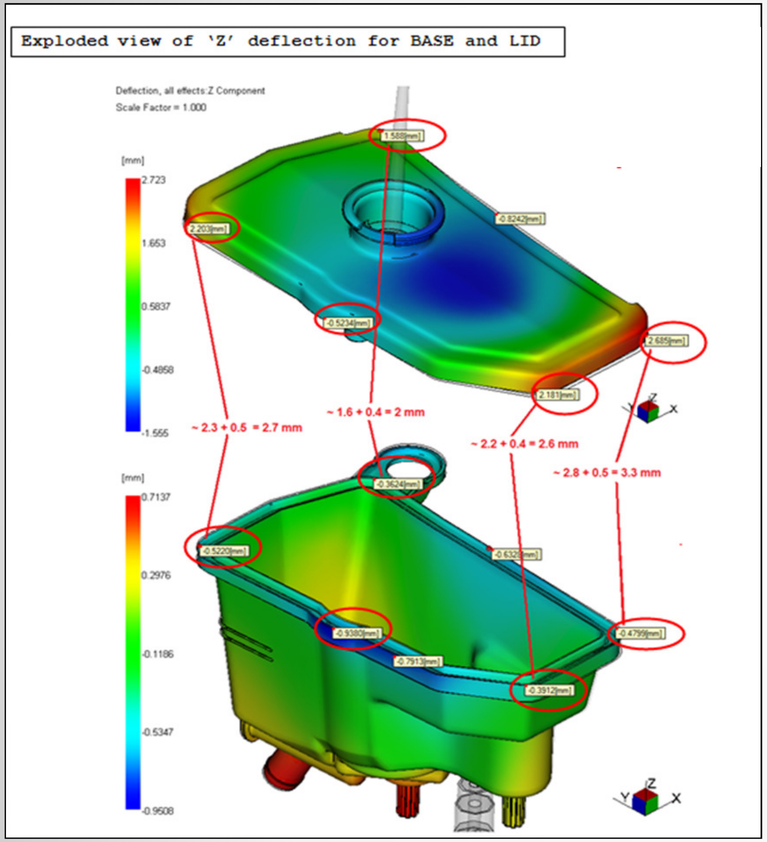
Assembly level deflection=1.83mm

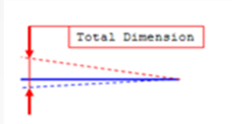


Assembly level deflection=1.48mm

- Final Conclusion:

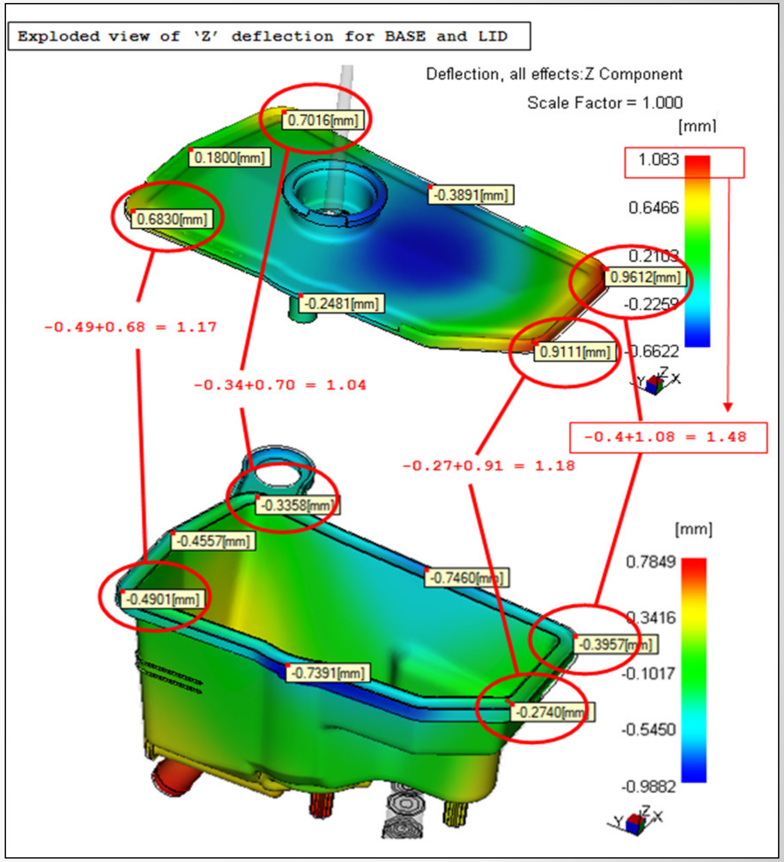
Original design of base, Lid and Feed as per tool





After series of part, gate modification

Lid part modification, minimal change in Feed



Overall Maximum Z deflection (very critical for FLATNESS) of assembly is 3.5 mm

Overall Maximum Z deflection (very critical for FLATNESS) of assembly is 1.4 mm

3.5 mm → 1.4 mm

5. Conclusion:

- Part design changes helped to reduce the deflection making assembly more stable for welding.

- We understood the effect of in-mold stress in original cases & that learning we had captured by developing this methodology.

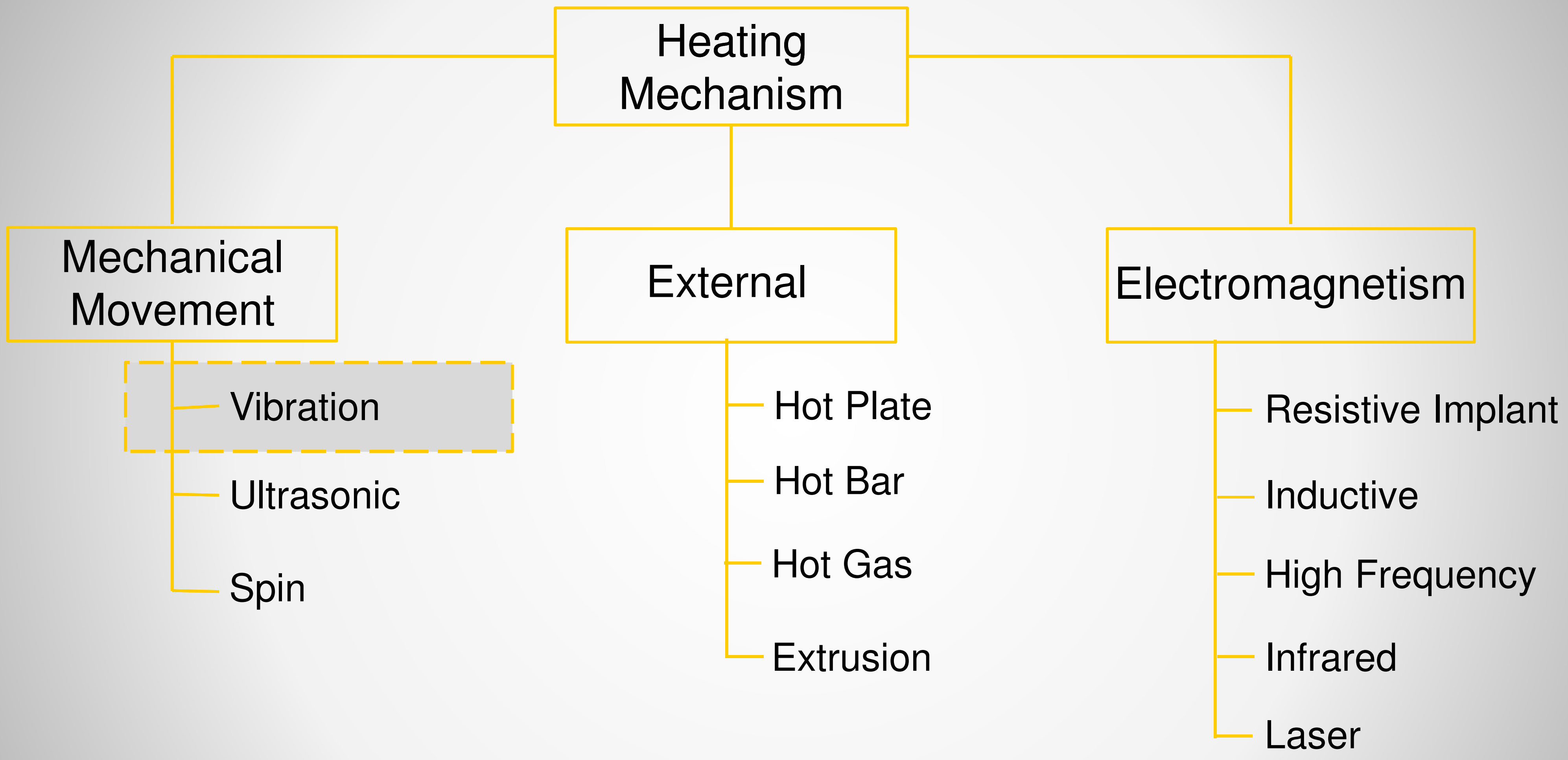
- Analysis on individual parts yields satisfactory results but assembly level study is helpful to avoid surprises in later stages.

- We have observed better results after following this approach for other welded assemblies & also got better correlation.

Plastic Welding techniques:

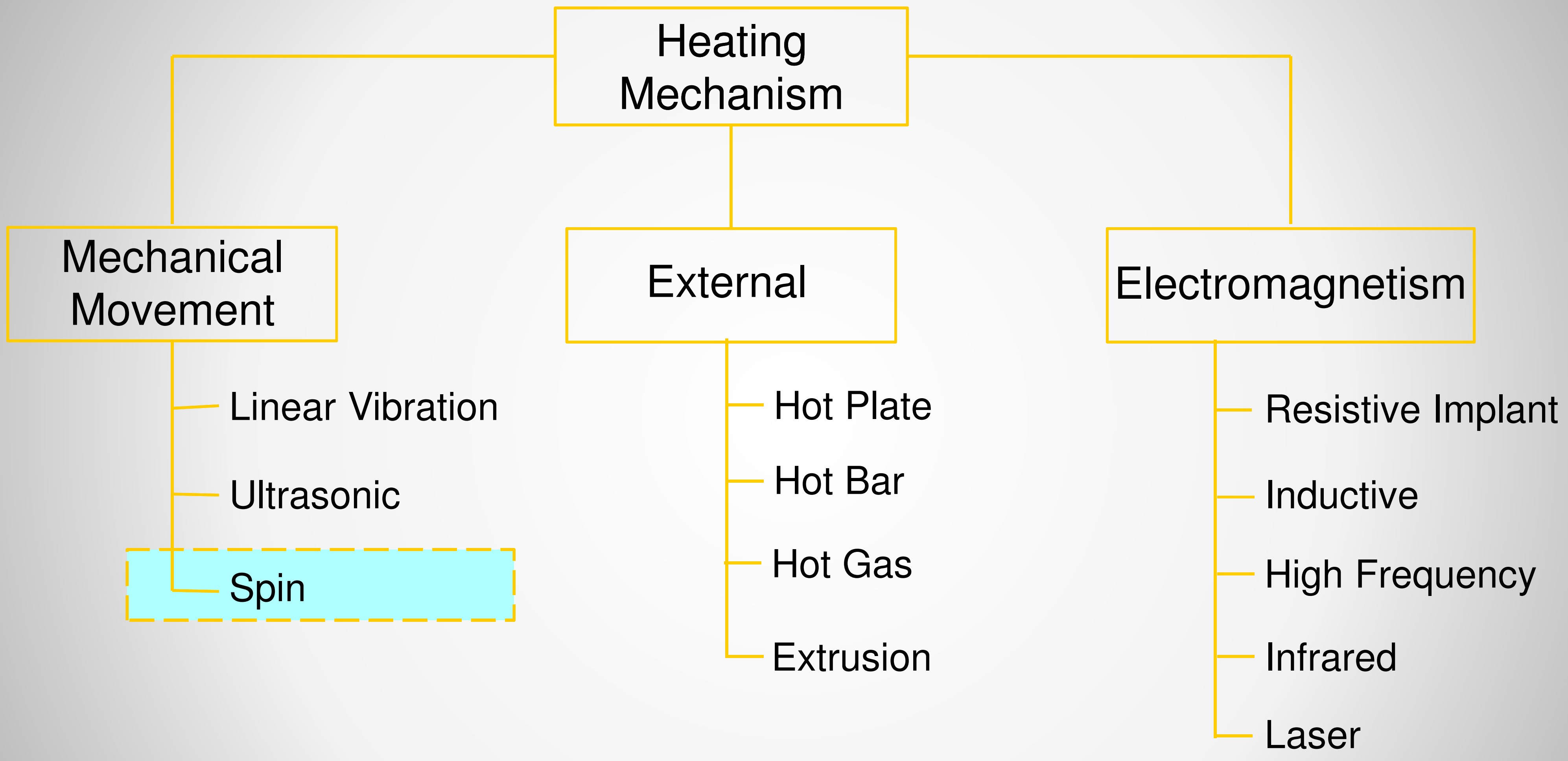
- **Heating Mechanism**
  - Mechanical Movement
    - Vibration
    - Ultrasonic
    - Spin
  - External
    - Hot Plate
    - Hot Bar
    - Hot Gas
    - Extrusion
  - Electromagnetism
    - Resistive Implant
    - Inductive
    - High Frequency
    - Infrared
    - Laser

▪ Plastic Welding techniques:



Key note of this slide: This approach is more relevant to vibration welding technique.

Plastic Welding techniques:



Key note of this slide: Work is in progress to develop methodology to study weld area for this technique.

6. Project Team :

Jaguar & Land Rover:

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(Tech Specialist, MDO)

Tata Technologies:

Mr. Ajay Virmalwar
(Sr. Project Manager, CAE)

Many thanks to team for their continuous support in all our endeavors & for providing data relevant to this presentation and inputs on correlation.

7. Q & A:

Thanks a lot for your valuable time!

Any Questions ?

Session Feedback

- Via the Survey Stations, email or mobile device
- AU 2015 passes given out each day!
- Best to do it right after the session
- Instructors see results in real-time

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