CAE method for the compression molding of discontinuous fiber reinforced thermoplastics, Part 2: Sheet form

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Sep 7th. 2018

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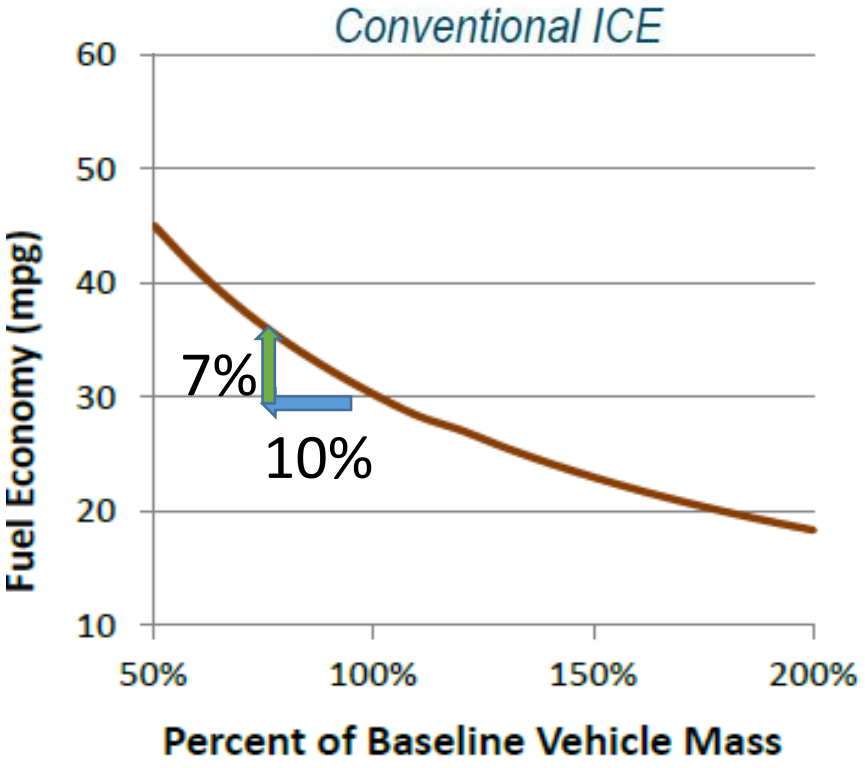
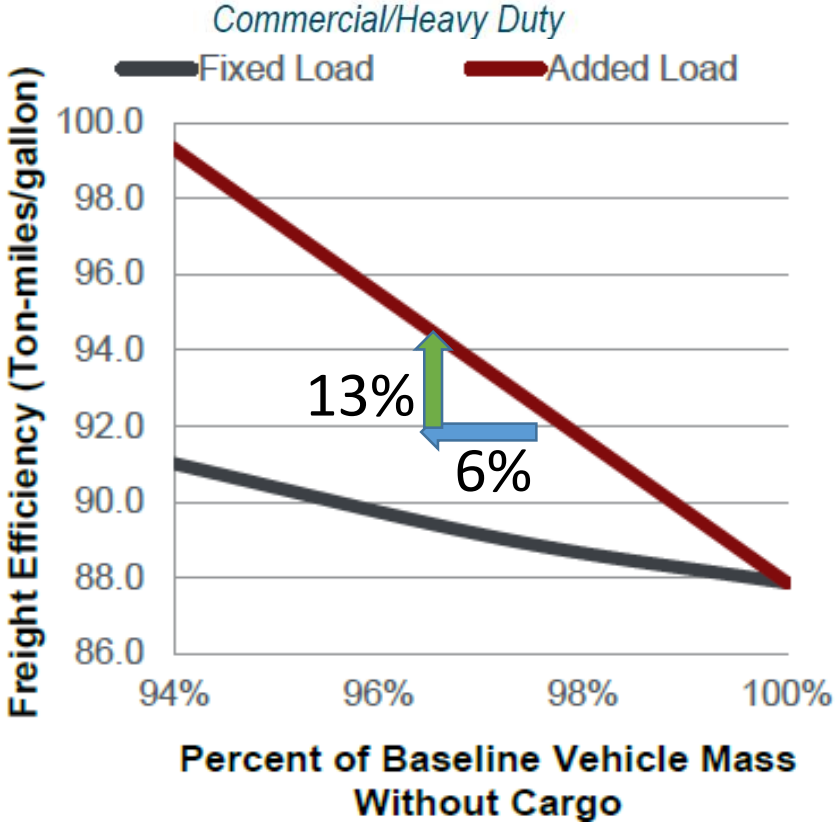
2. Challenges and approaches
3. Experimental studies on compression molding using sheet materials
4. CAE studies on compression molding using sheet materials
5. Conclusions

1. Background

The Fuel economy is directly related to vehicle weight

Source DOE

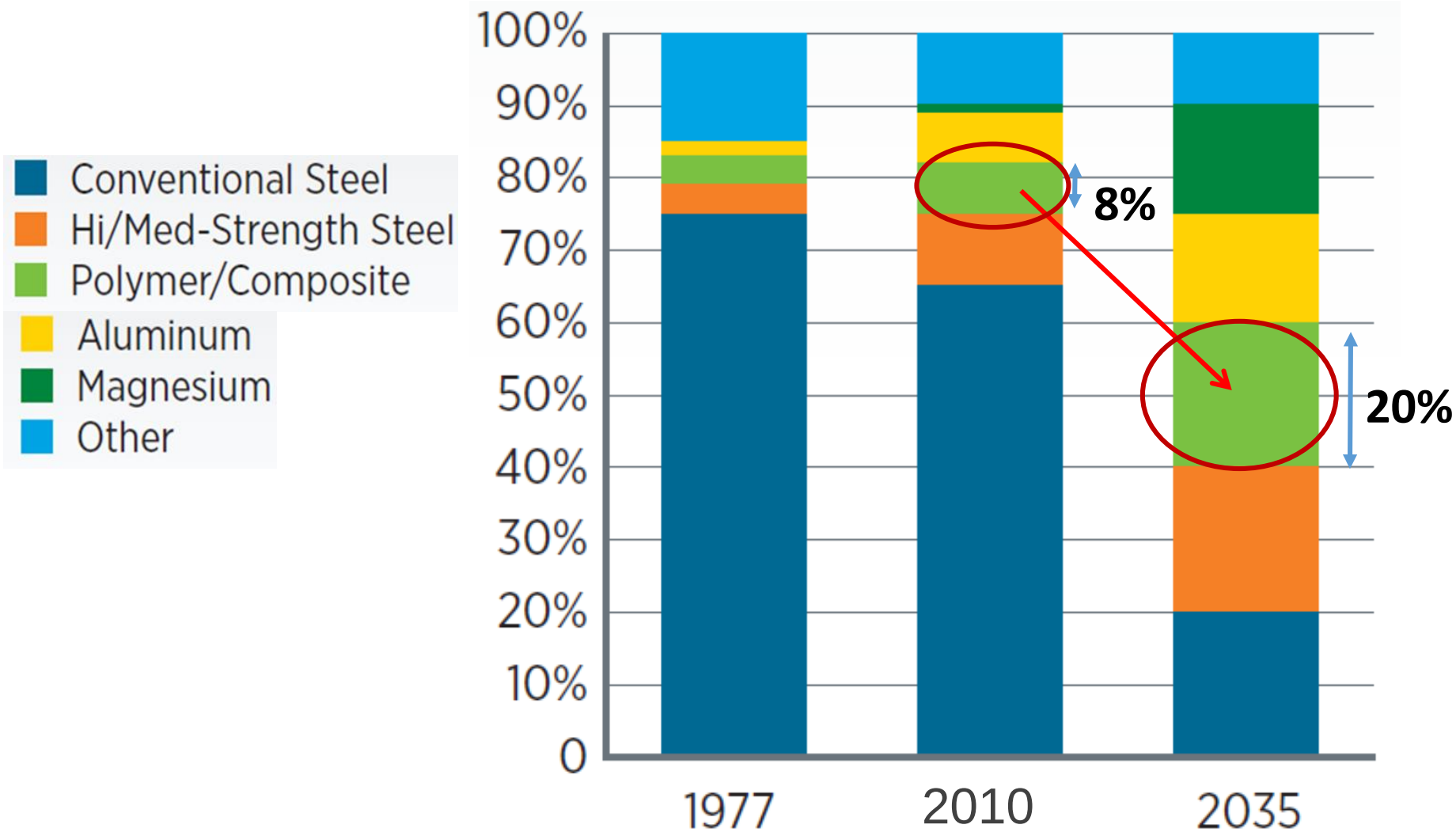




Reducing vehicle weight is very important

1. Background

Trend for light weighting material used in a car

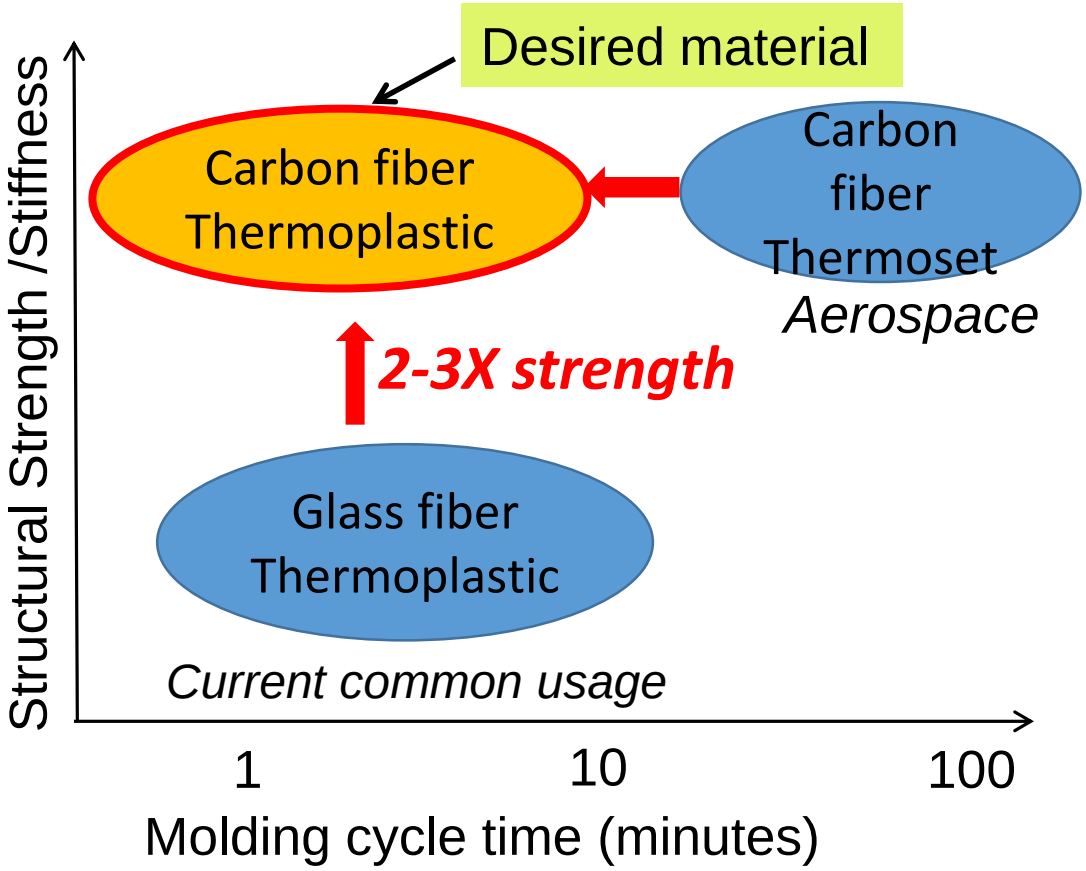


Source; DOE

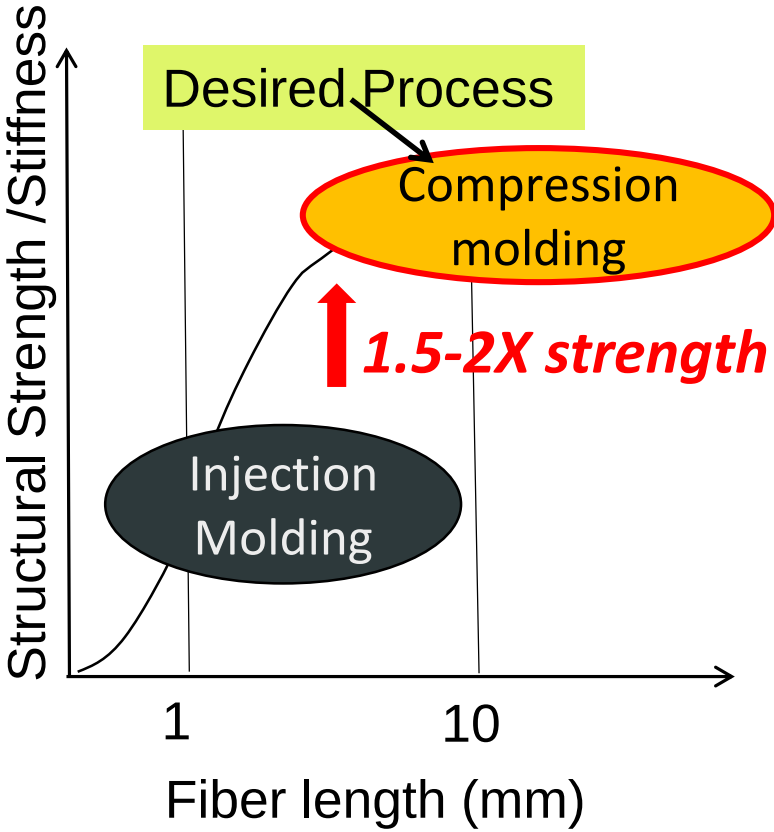
1. Background

How to manufacture FRP

What kind of FRP materials is better?



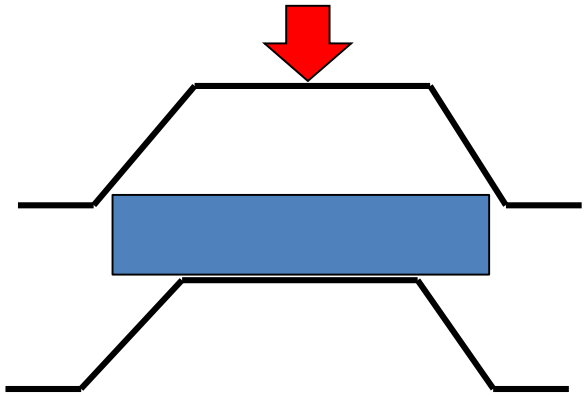
Which process is better?



CF+Thermoplastic made by compression molding is our interest.

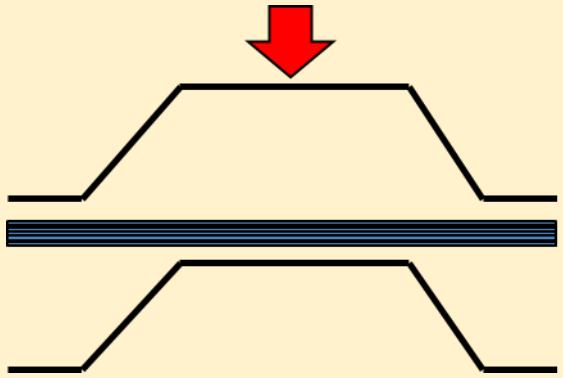
2.Challenges and approaches

a) Bulk material:



Compression molding of extruded

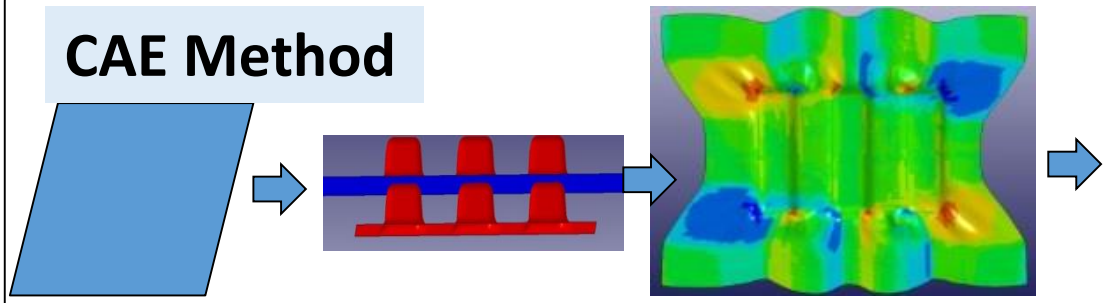
b) Sheet material:



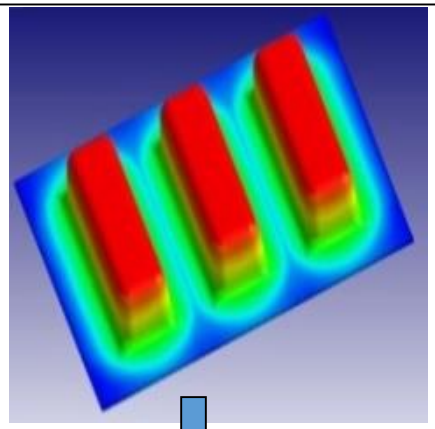
Compression molding of sheets

2.Challenges and approach for sheet material

CAE Method



Draping of the composite sheet material



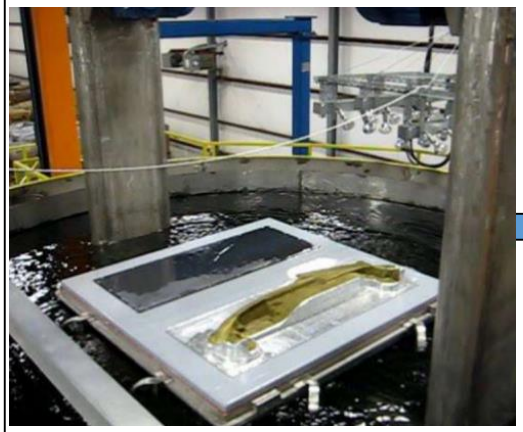
Judgement parameter

Compare and judge

- Warpage
- Fiber orientations

OK?

Physical Testing



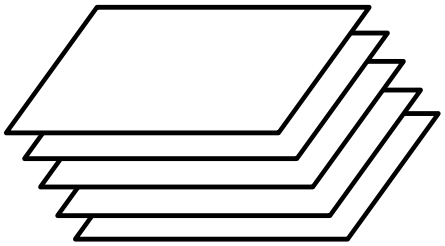
CF+PA6 sheets, water slurry process

Actual part made at University of Tennessee

2.Challenges and approach for sheet material

CAE: Compression molding of CF Sheets – Development activity

Possible condition of fibers in the sheet

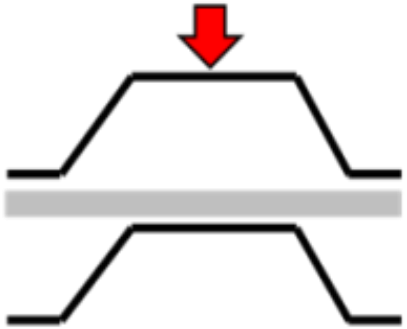


Stack of Sheet 0.2 mm thick

Heat (250-300C)

1

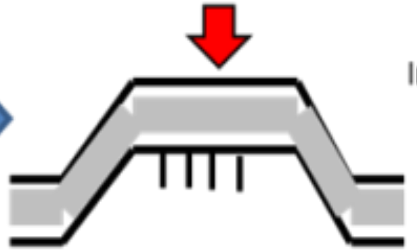
LS-Dyna



Stack of thin CF+PP sheets formed at high temperature

2

(initial Fiber condition)



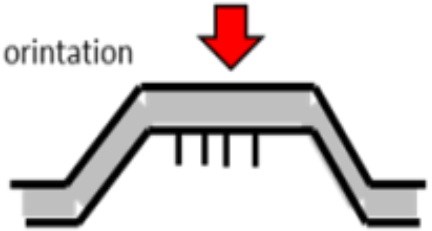
Thermoforming
- Draping sheet in the cavity

3

Moldex3D

Moldex 3D
(fill corners ribs etc)

Initial Fiber orintation



Compression
– Squeeze to fill cavity completely

4

Warpage etc

3.1 Results: Part build: sheet material preparation

Fiber: (34% by weight)

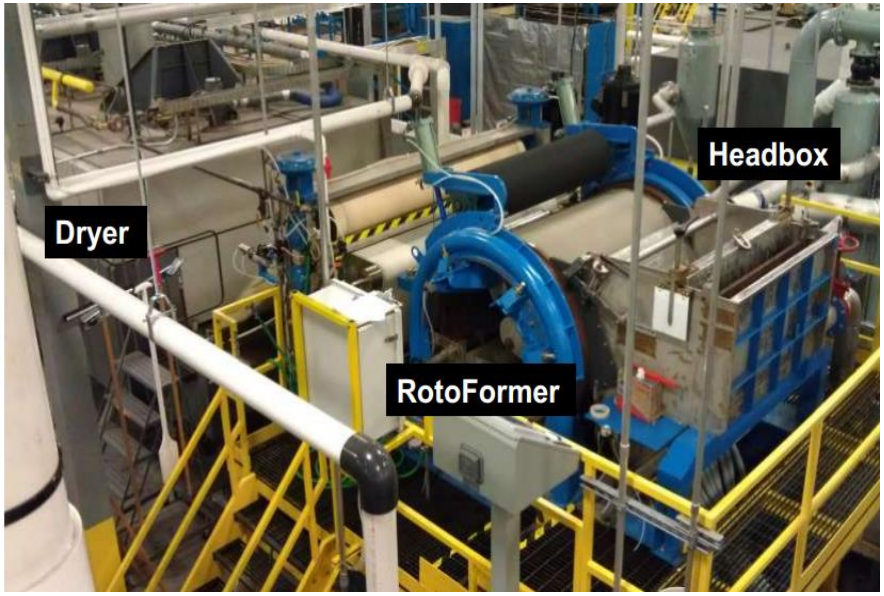
- **RCF Intermediate Modulus**
- **12 mm long , dia 6-7 micron**
- **Random orientation**

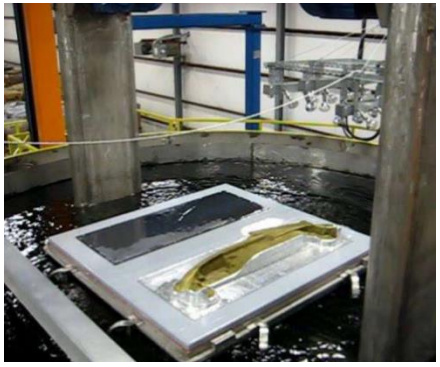
Resin

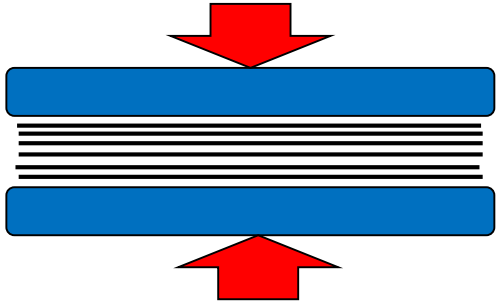
- **PA6 and PA66 fibers**
- **6-12 mm long, dia:20 micron**

Binder

- **2% Tawron**







0.2 mm Thick sheets are stacked to get 2 mm thick sheets. Some are heated under pressure to Pre-consolidate

14x10 inch fluffy sheets are prepared

3.2 Results: Part build and measurement

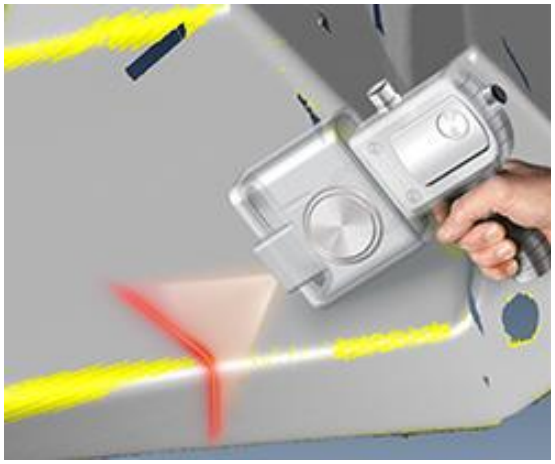
Part build

35%CF+PA6 sheets

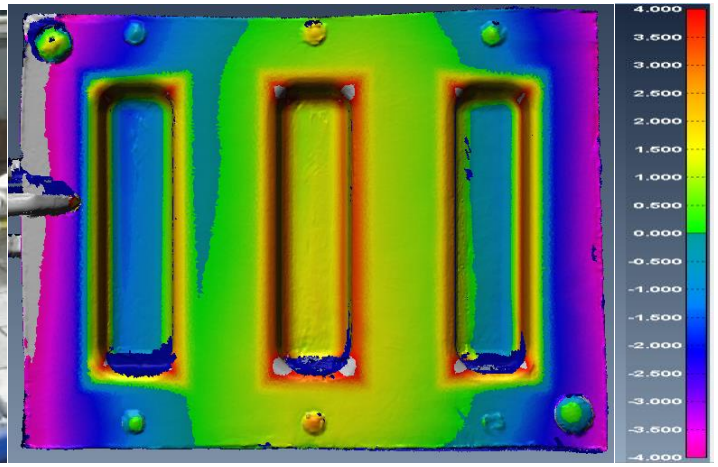
Sheet under compression

Final part

Warpage measurement



Scanning of the sampling using Fero-Arm



Warpage contour

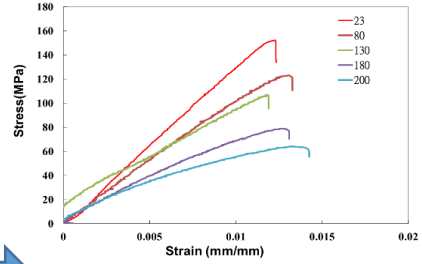
3.3 Material properties measured for CAE studies

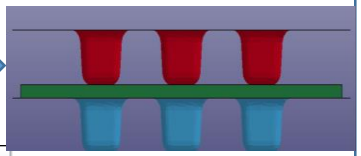
1. Measurement of high temperature properties of sheet material for draping analysis

1. Using hot press machine to make the sheet material harder

2. Cut it into test pieces

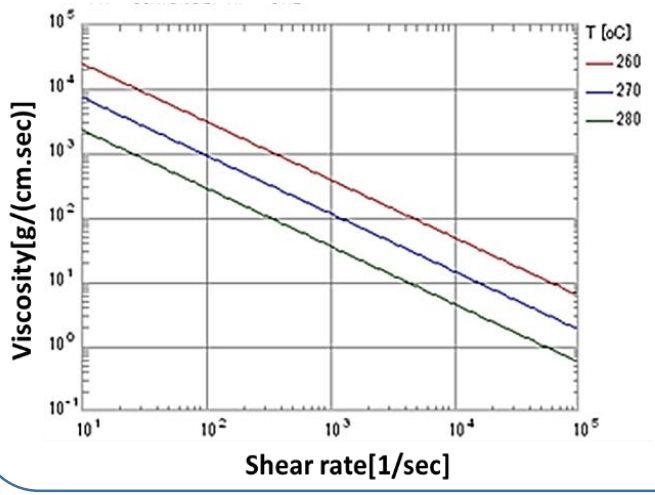
3. Tensile test using instron 5966 following ASTM D638

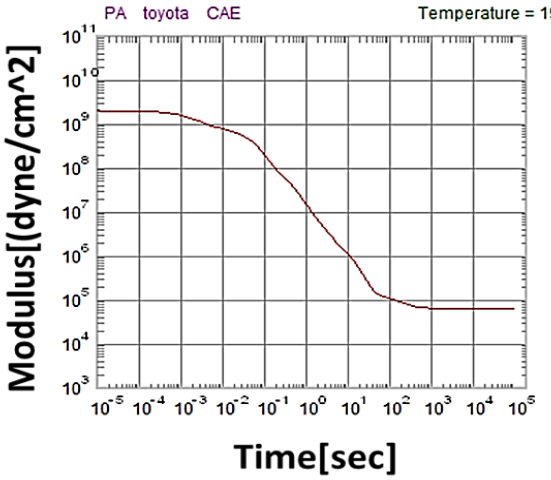


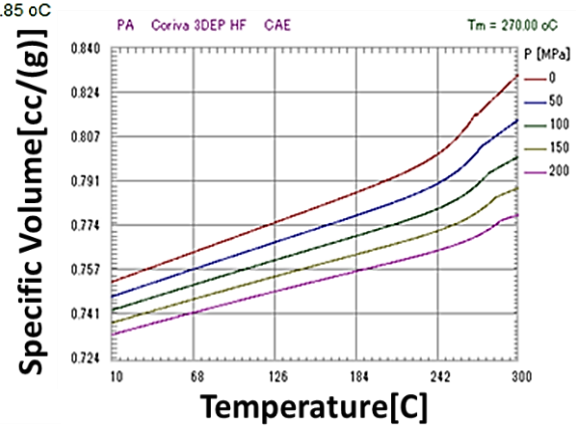


Temp	Modulus(Mpa)	Poisson's ratio
23	14091	0.339
80	10444	0.239
130	10118	0.237
180	8728	0.179
200	7380	0.403

2. Viscoelastic material properties measured for compression molding analysis



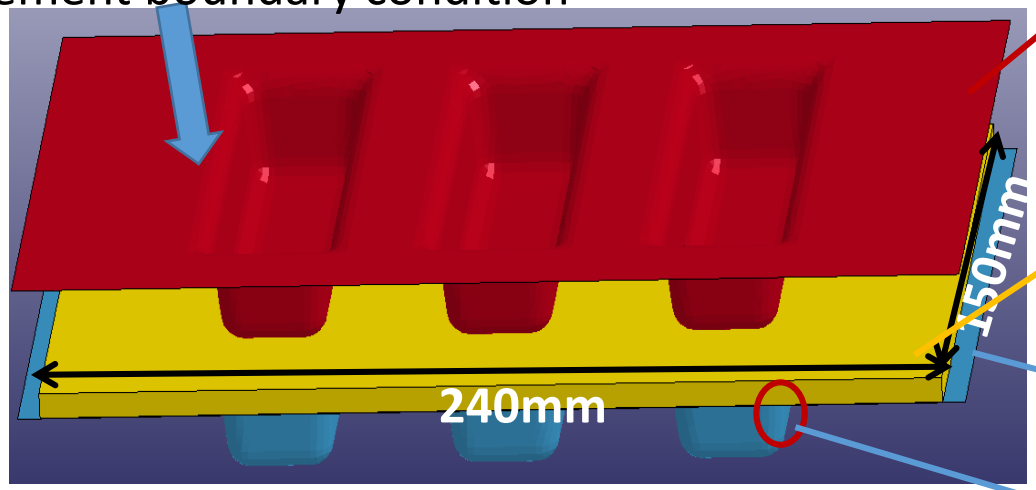




4.Results: Draping analysis of sheet material

LS-DYNA material model

Displacement boundary condition

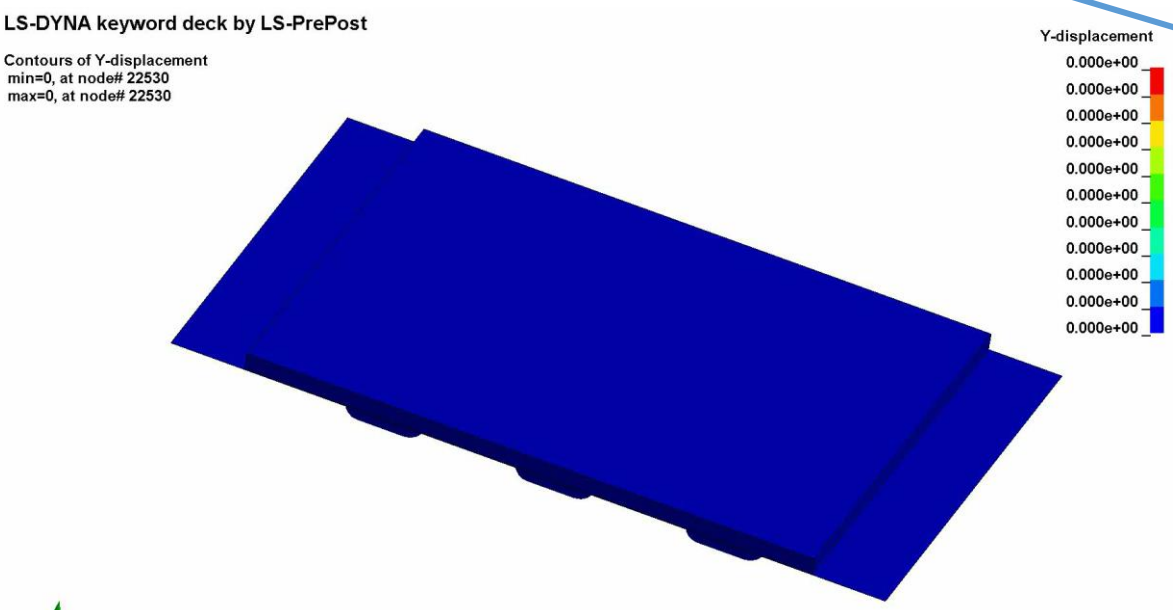


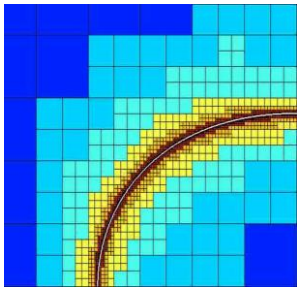
Top punch

Sheet material
(T=4mm)
initial Temperature
270C

LS DYNA Mat 4
Solid elements

Mold base
temperature 100C

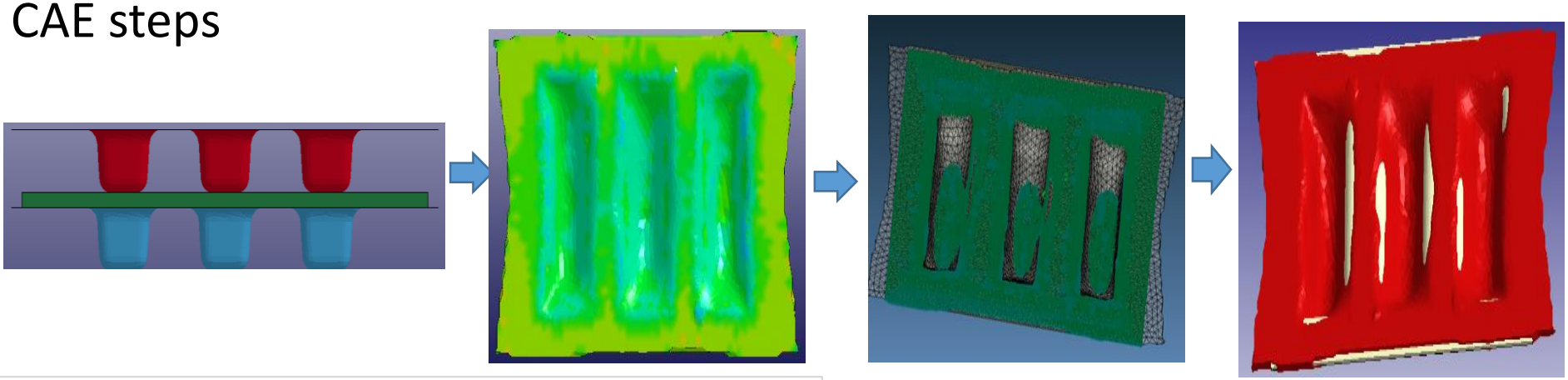


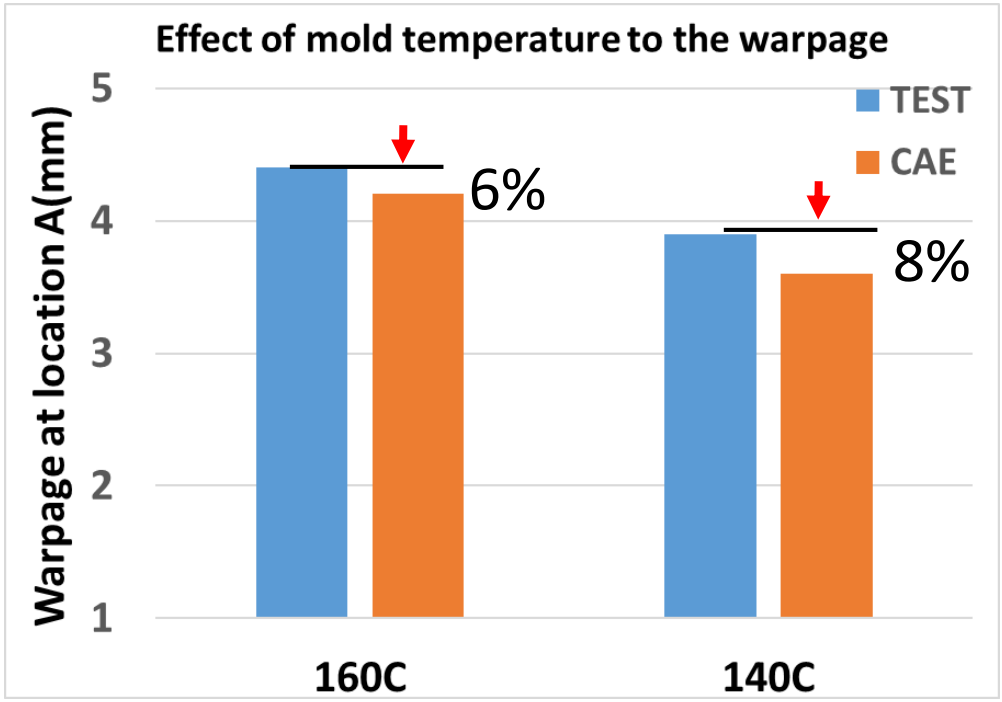


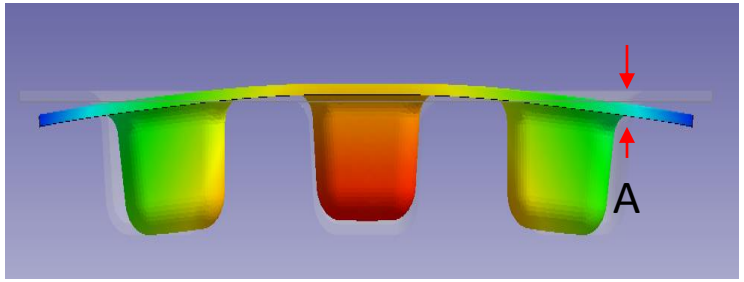
Adaptive re-meshing
technique applied

4.Results: Warpage Comparison

CAE steps





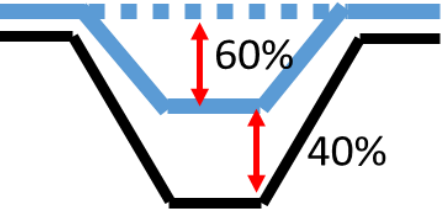


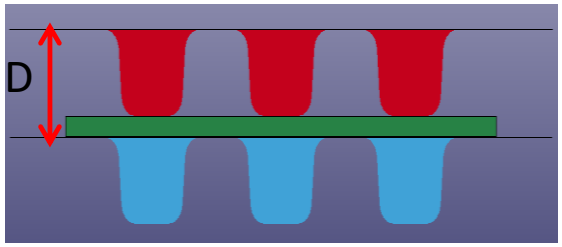
Warpage

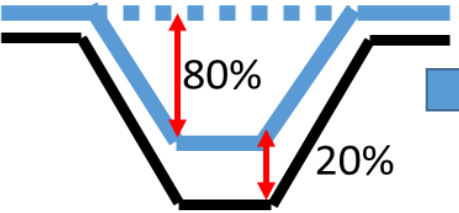
Warpage predicted using the approach matches with measurements

4.Results: Draping of sheet material

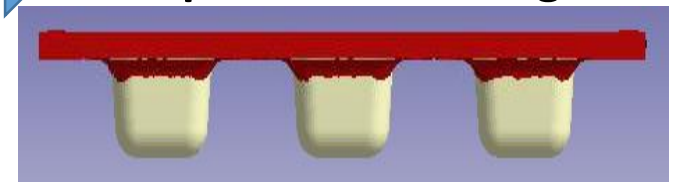
When to stop stamping (stroke) and start compressing in CAE ?

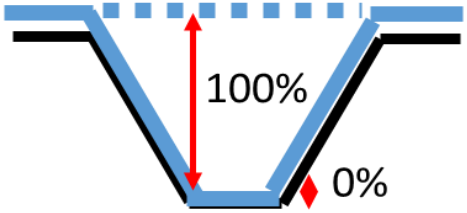






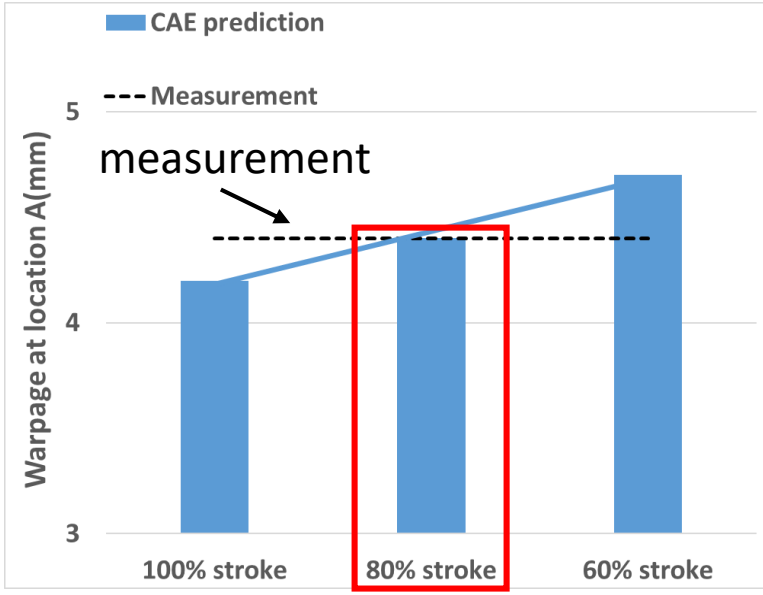
Transfer to Moldex3D and compression molding





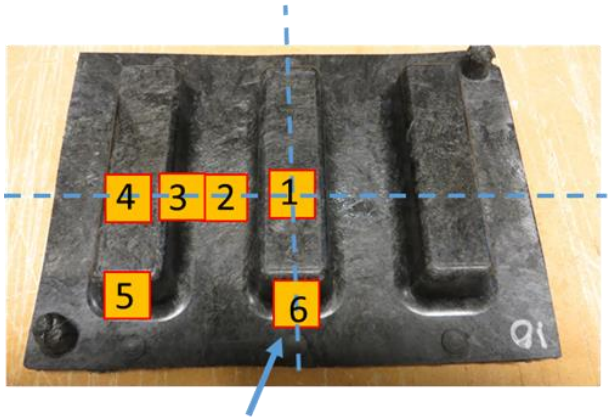
When to stop draping ?

Results

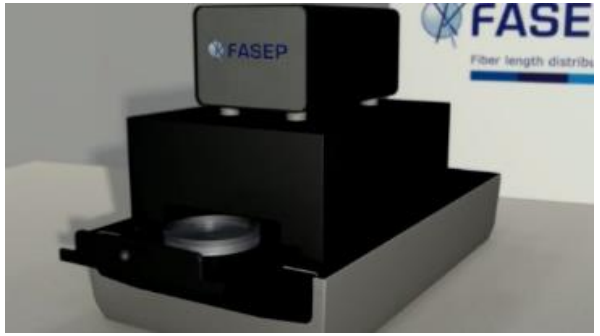


LS Dyna stroke 80% then compressed will have better correlation with measurement

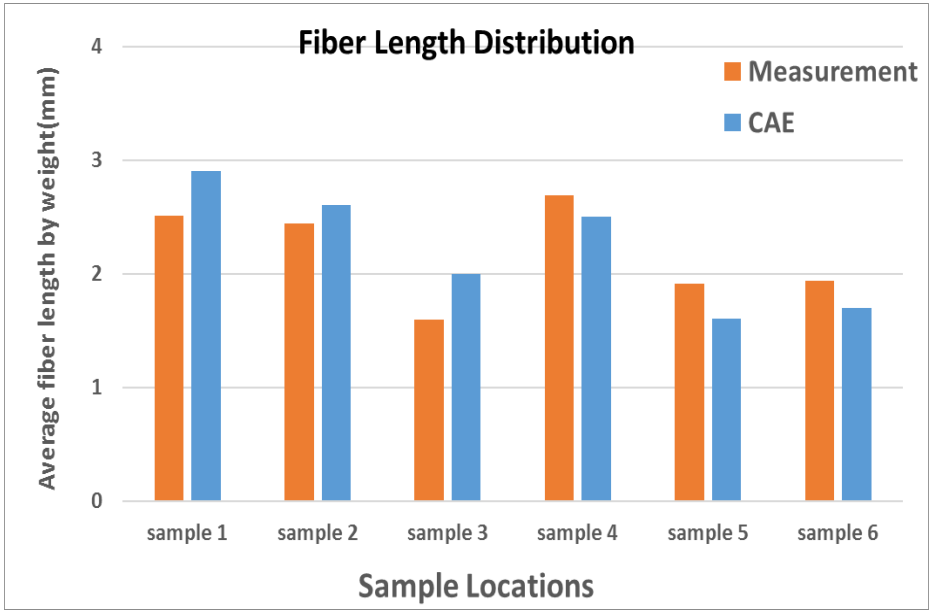
4.Results: Fiber length measurement results



Sample locations



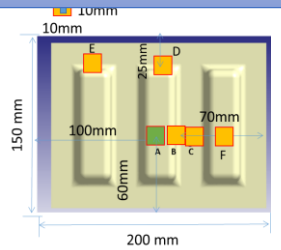
FASEP method to measure fiber length

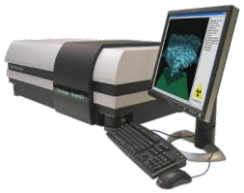


4.Results: Fiber orientation measurement and comparison

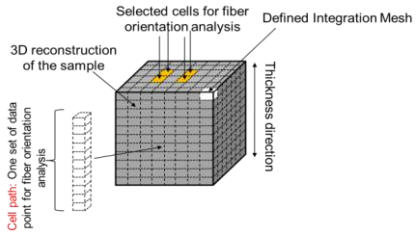
Development process and steps

Fiber orientation measurement



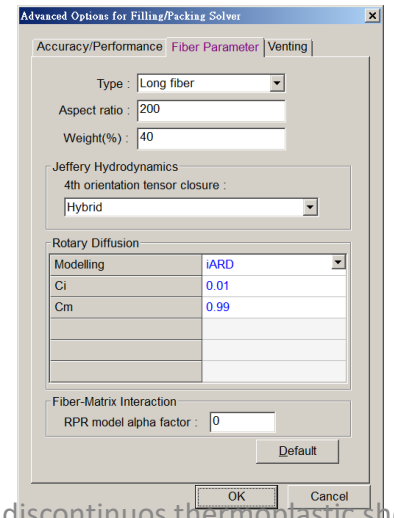


VOLUME GRAPHICS
SOLUTIONS ABOUT VOXELS



Cut sample from part → **CT scan images of the part** → **Volume graphics Image analysis** → **Fiber orientation results (*.txt)**

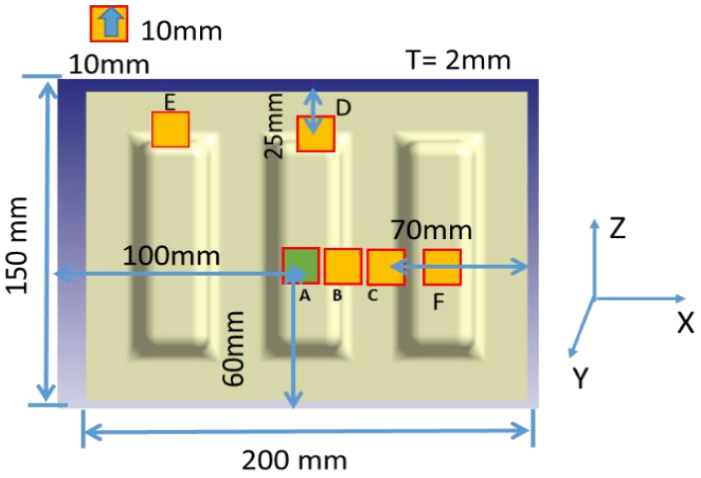
Fiber orientation in CAE

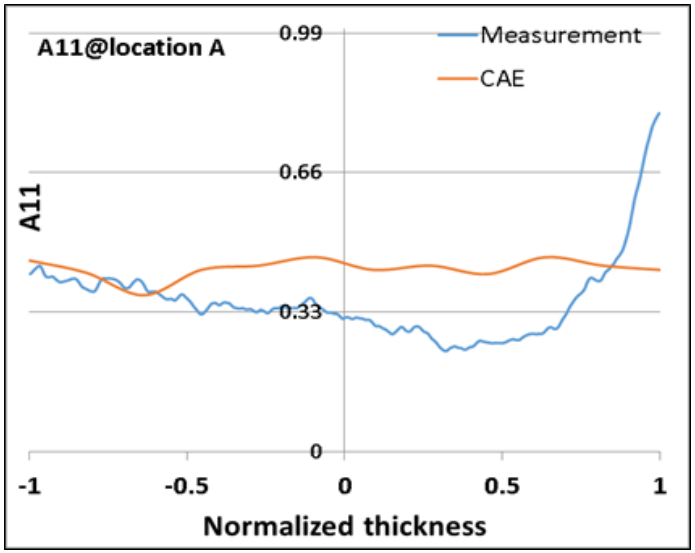


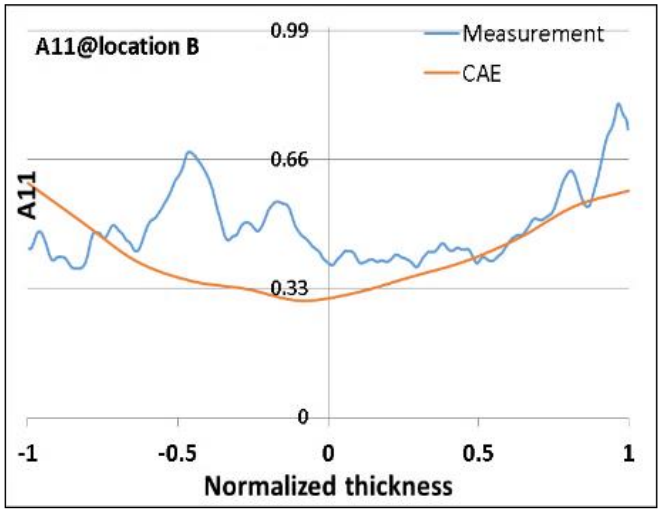
Compression molding of long glass fiber reinforced composite:

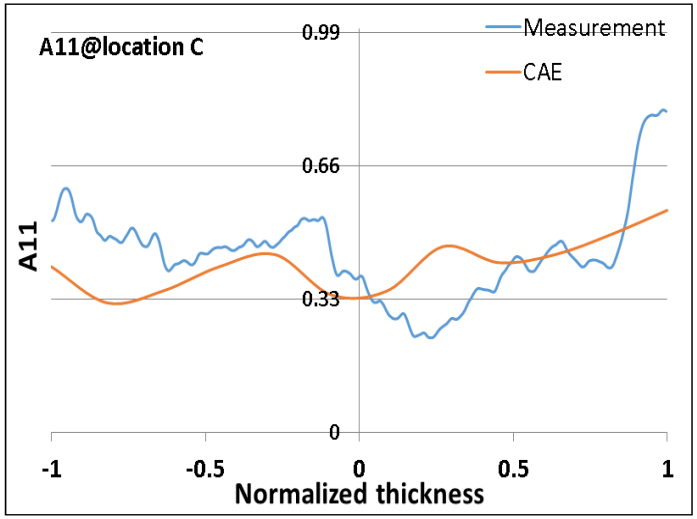
- iARD–RPR model is used:
- AR=300
- Cm = 0.005,
- Ci = 0.1

4.Fiber orientation measurement results









5.Conclusion

- A two step CAE method is developed for compression molding of CFRP in sheet format
- The warpage prediction of the three cavity part is validated from the test results
- The fiber orientation and fiber length of the final part is also validated between test and CAE method
- The draping distance will have effect for the final warpage of the part after compression molding