Simfot: Effects of forming methods on shape distortions of composites

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NFFP6 Simfot – Simulation of composite manufacturing process from forming to demolding

Transfer of results from forming to shape distortion calculation

Material characterization – Swerea Sicomp

Process induced residual stresses – Saab, Creo Dynamics

Measurement technology – Creo Dynamics

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Material characterization – Swerea Sicomp

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Measurement technology – Creo Dynamics

Background

We have previously used FE-software to simulate manufacturing of stacked uni-directional prepreg.

Now in the Simfot project we wanted to combine the results from forming simulations with shape distortions in an attempt to simulate the whole process chain

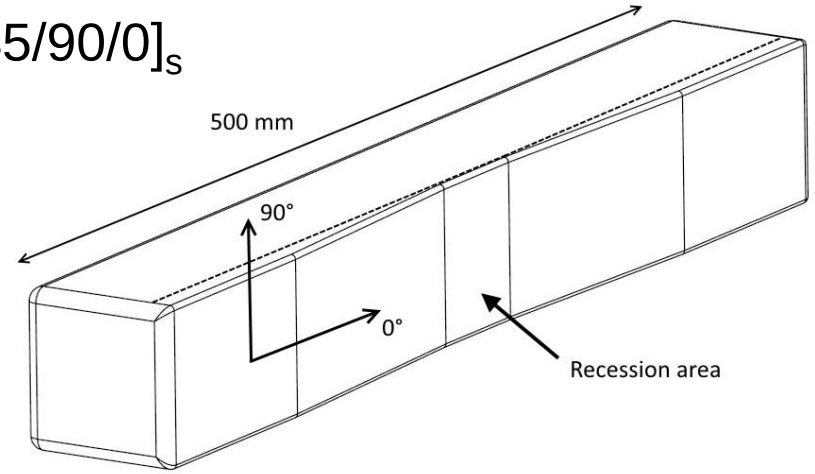
Additionally we want to investigate the effect of different forming methods on shape distortion

Geometry and material

A double-curved geometry was formed using two different methods. Hand lay-up and hot drape forming.

Uni-directional prepreg 0.13 mm thick

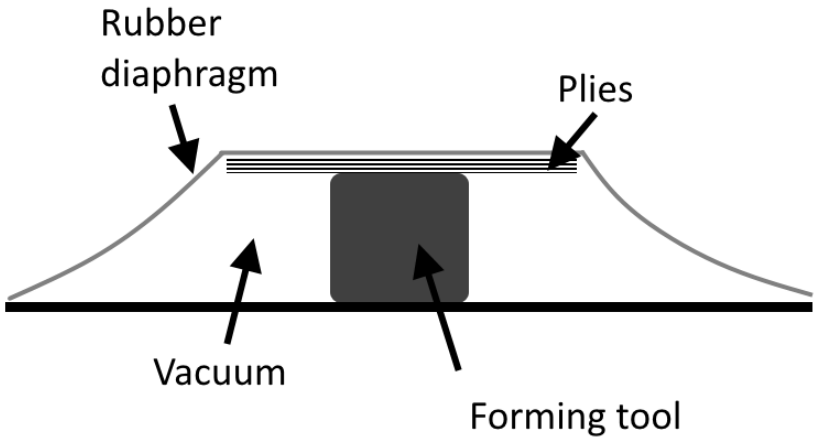
Stacking sequence $[45/-45/90/0]_s$

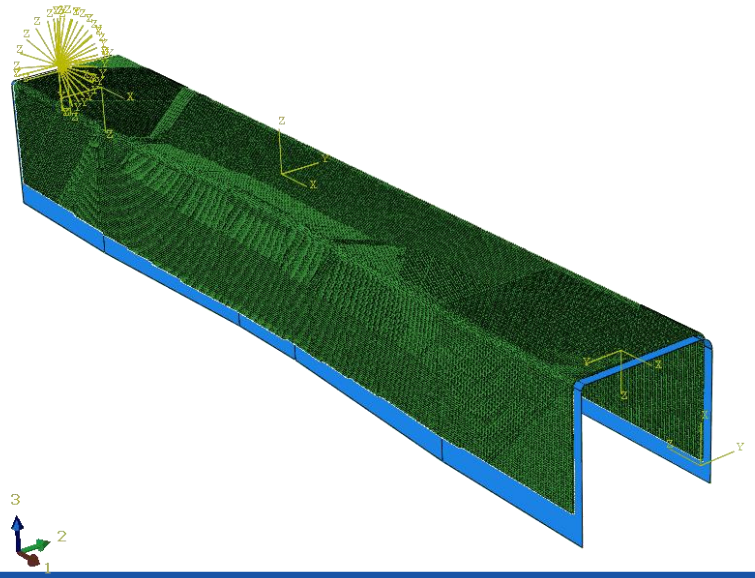


Manufacturing methods

Hand layup: Stack was split in to cross-plied pairs [(45/-45),(90/0),(0/90),(-45/45)] which were formed together

HDF: The whole stack is formed at once at elevated temperature





Manufacturing angles

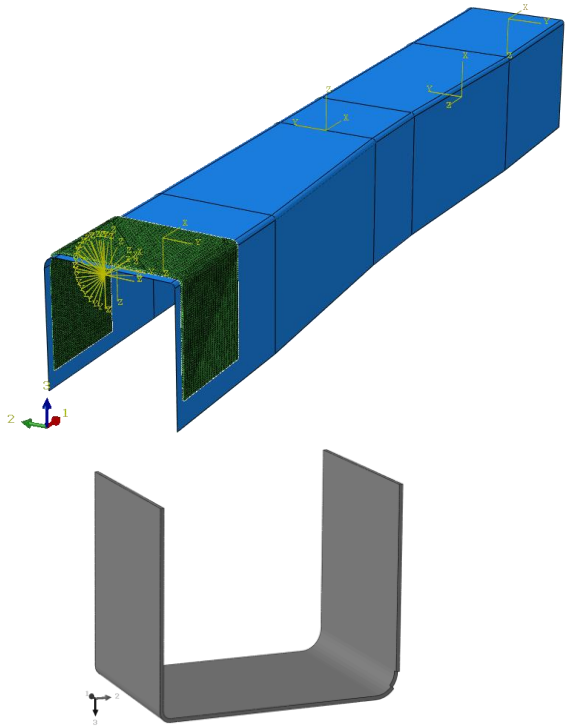
U shaped angles which only required 2D-deformation was formed to investigate the effects of different amount of plies.

Hand layup

8, 16 and 32 layers

Hot drape forming

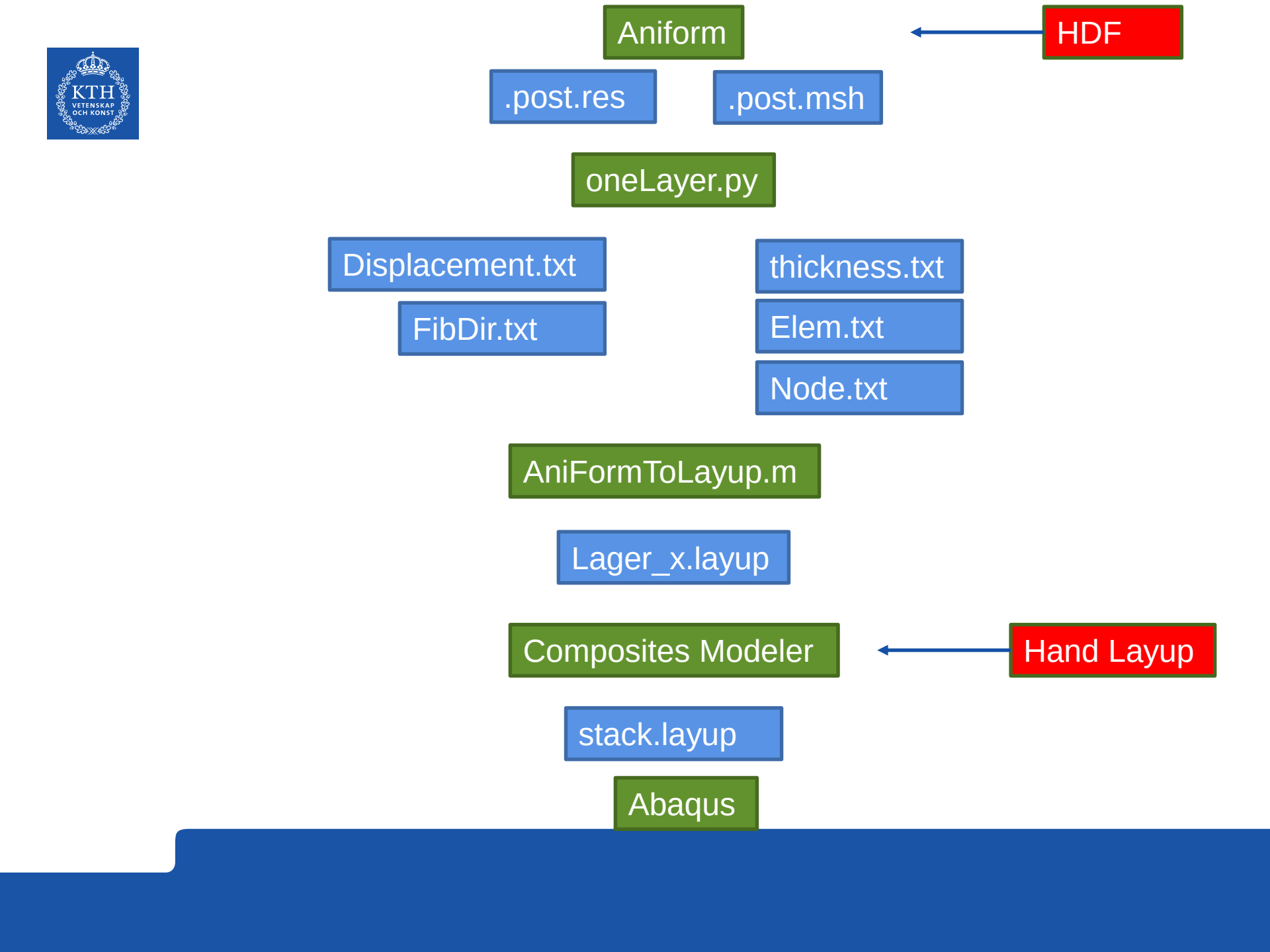
8, 16 and 32 layers



Simulation

Kinematic: The beam manufactured with hand lay-up was reproduced using composites modeler in Abaqus

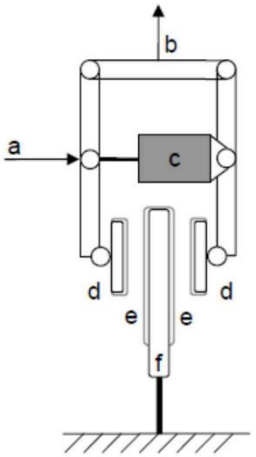
FE-model: The hot drape formed beam was simulated by using Aniform thus capturing fibre direction due to interactions between layers and thickness variations due to in-plane strains.


Aniform
HDF
.post.res
.post.msh
oneLayer.py
Displacement.txt
thickness.txt
FibDir.txt
Elem.txt
Node.txt
AniFormToLayup.m
Lager_x.layup
Composites Modeler
Hand Layup
stack.layup
Abaqus

Characterization of material

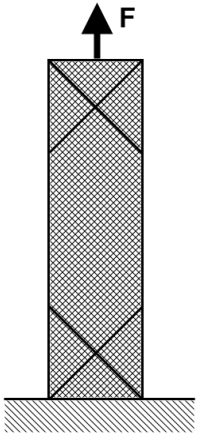
Inter-ply properties

Rate dependence



Intra-ply properties

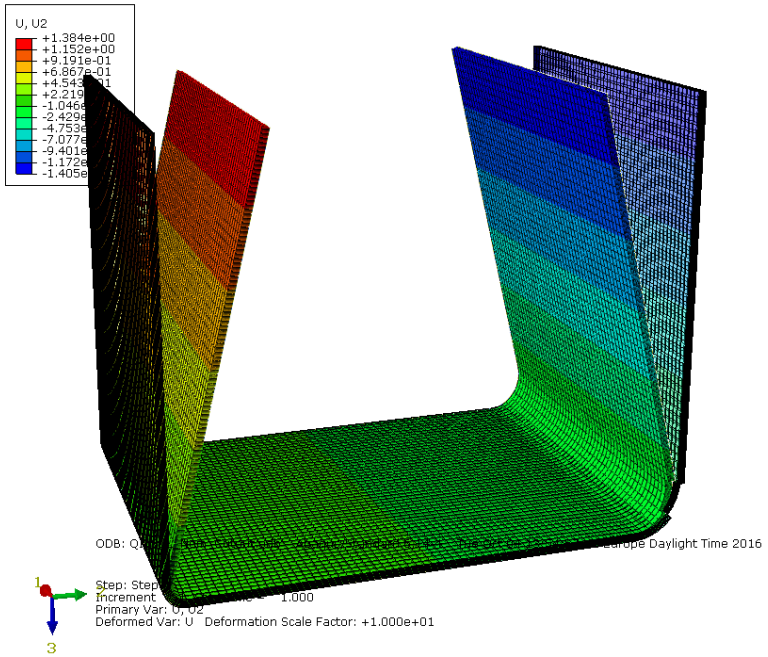
Rate and pressure dependence



Shape distortion calculation

Distortions occur due to a difference in coefficient of thermal expansion in the in-plane and out of plane directions

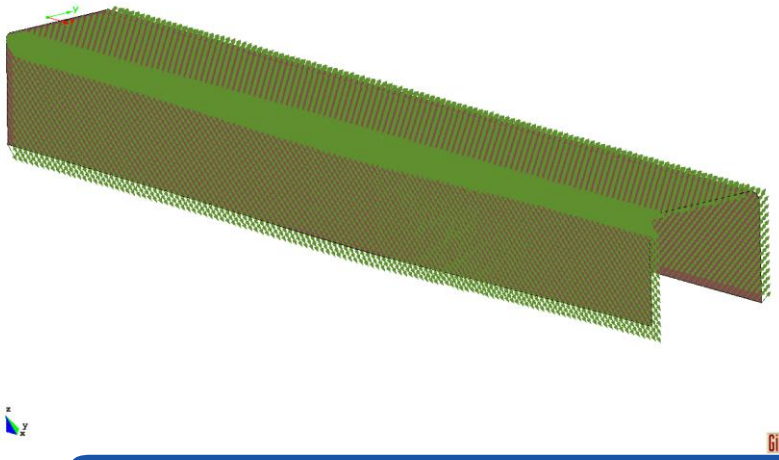
Modelled by applying a non-isotropic CTE and a temperature change

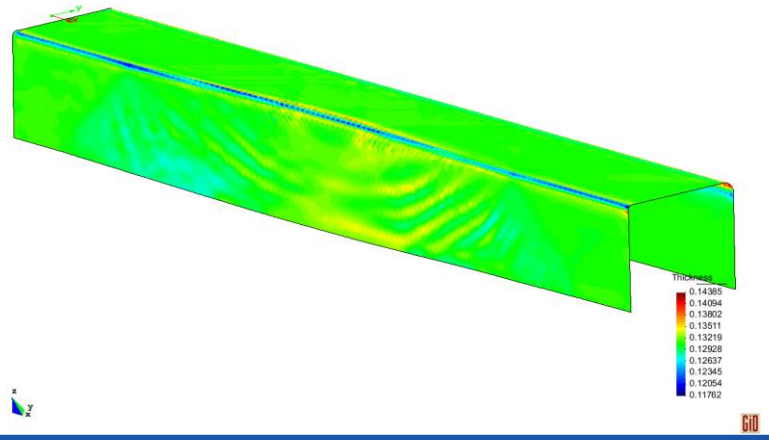


Transfer of results

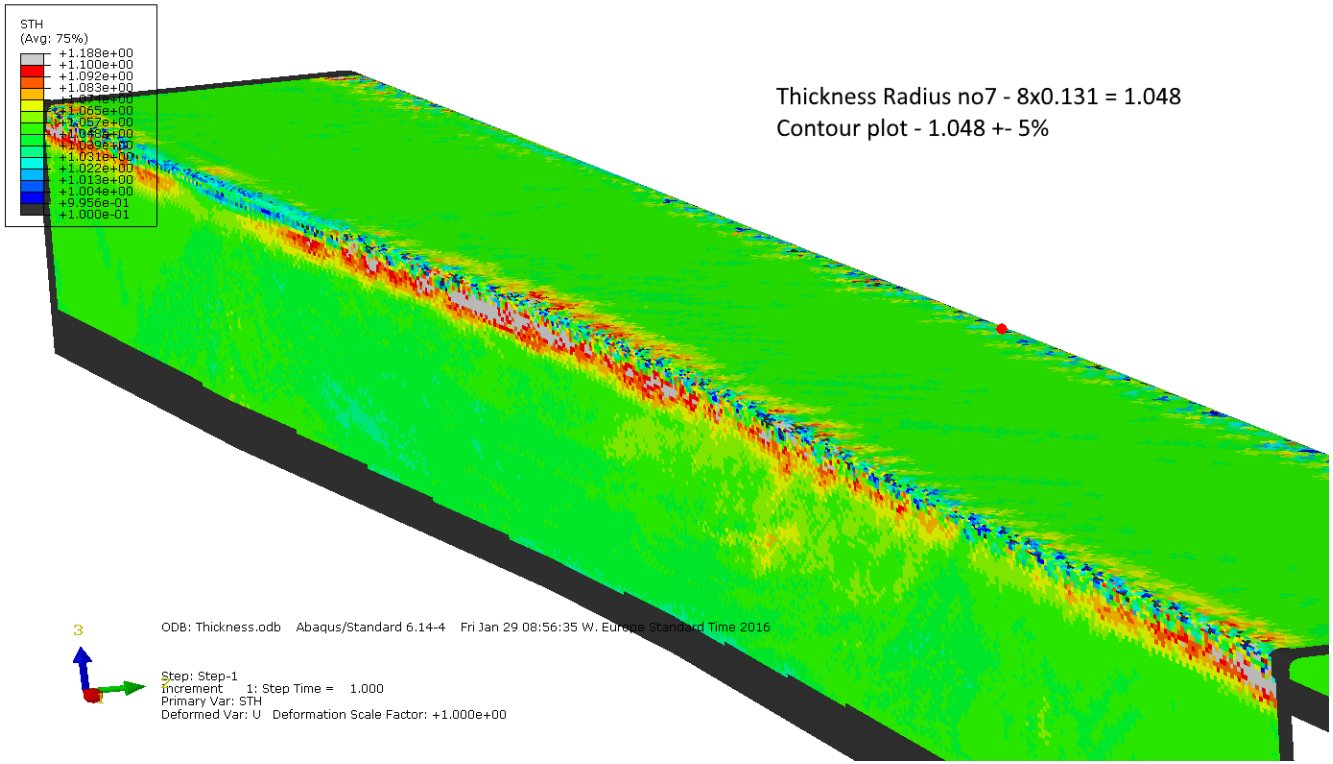
The results from Aniform where mapped ply by ply into a layup in composites modeler

The they are then combined into a single layup that can then be used to generate a solid model

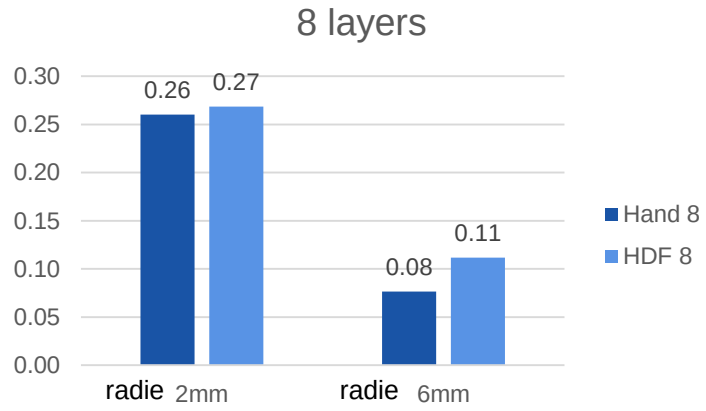


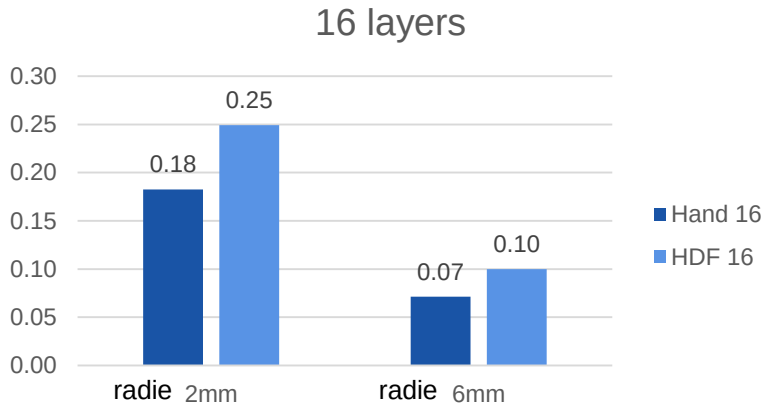


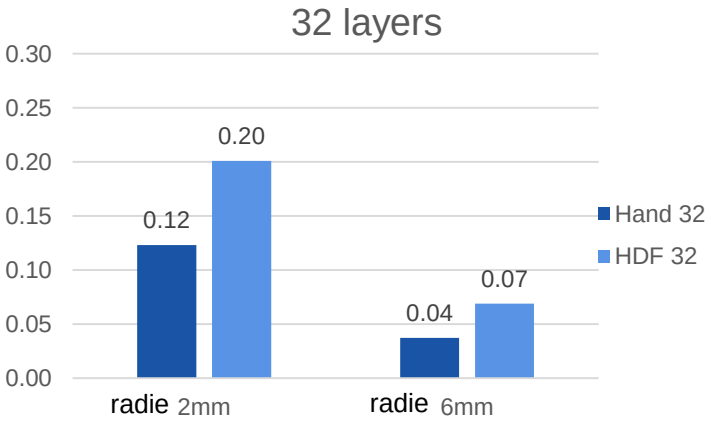
Thickness variation

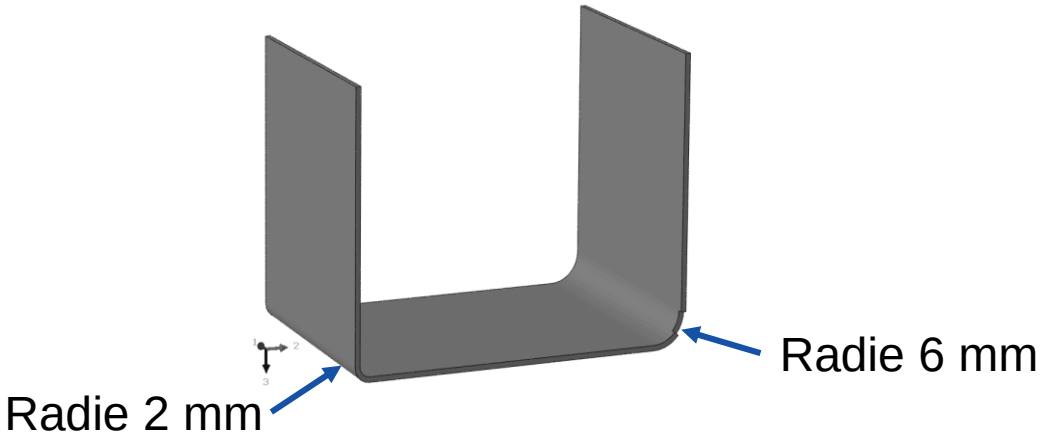


Radius thickness - experimental

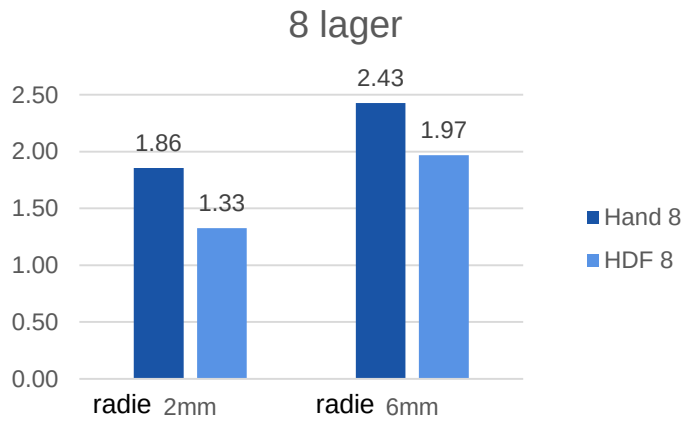


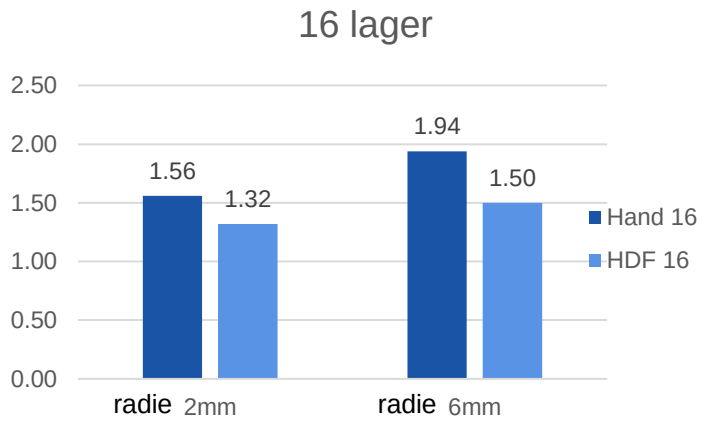


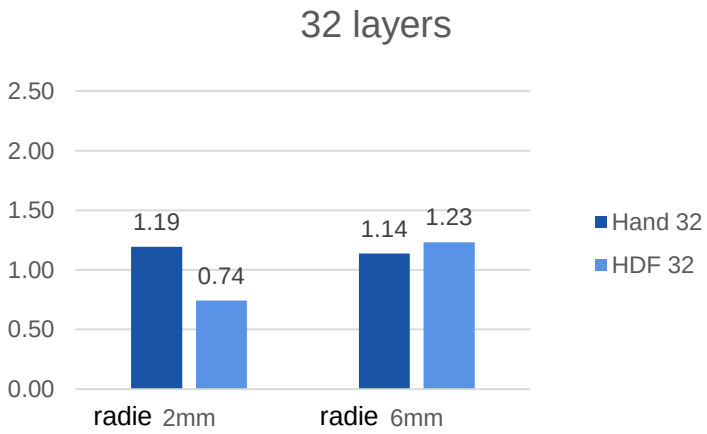


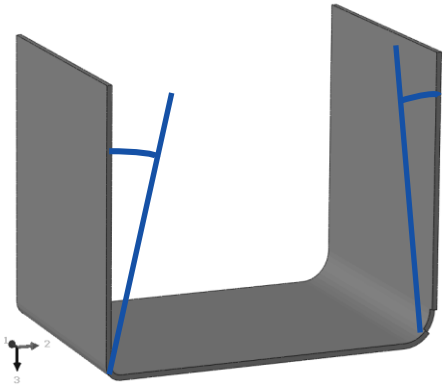


Effect on angle - experimental







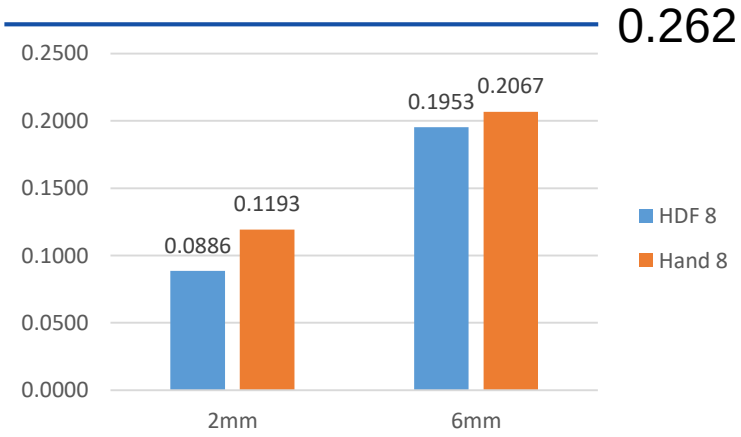


Radius thinning of zeros

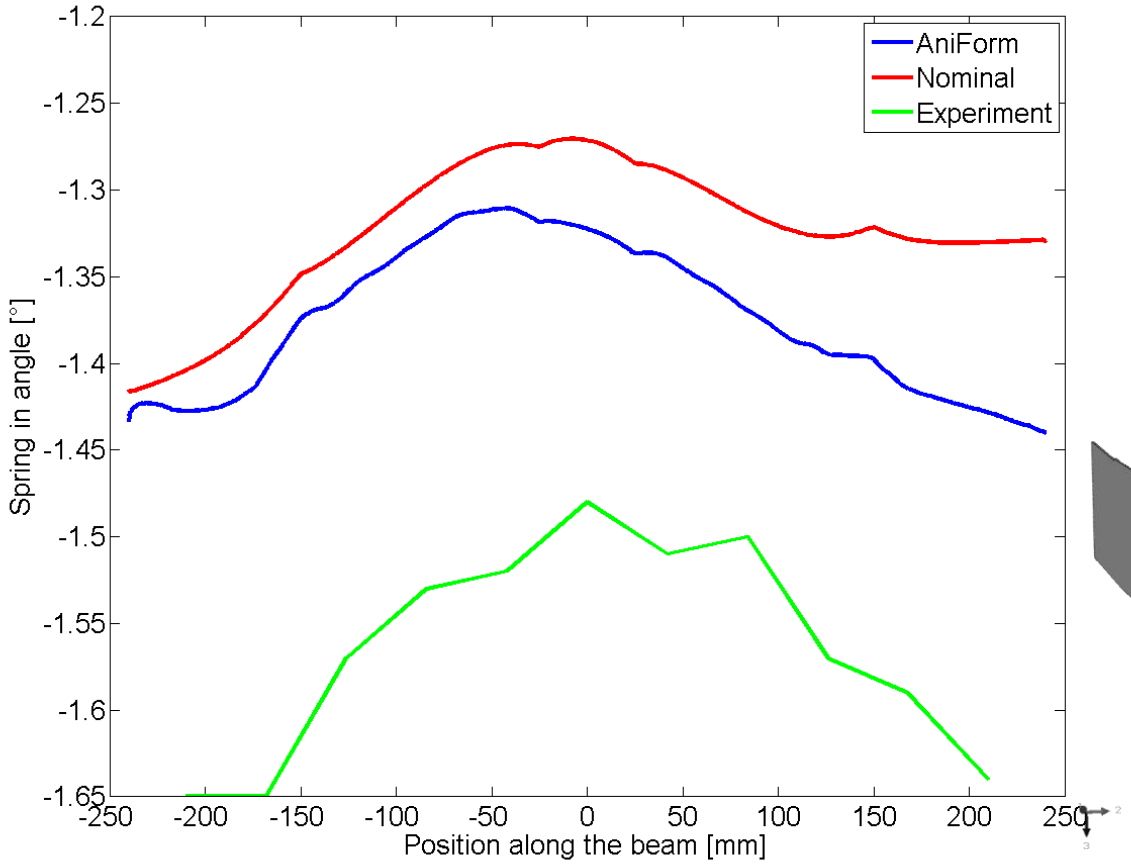
2 mm HDF

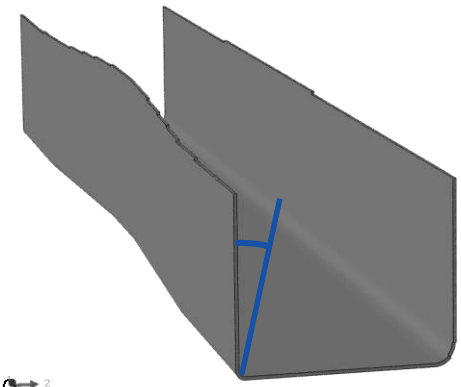
6 mm HDF

Substantial thinning of the zero degree ply occurs

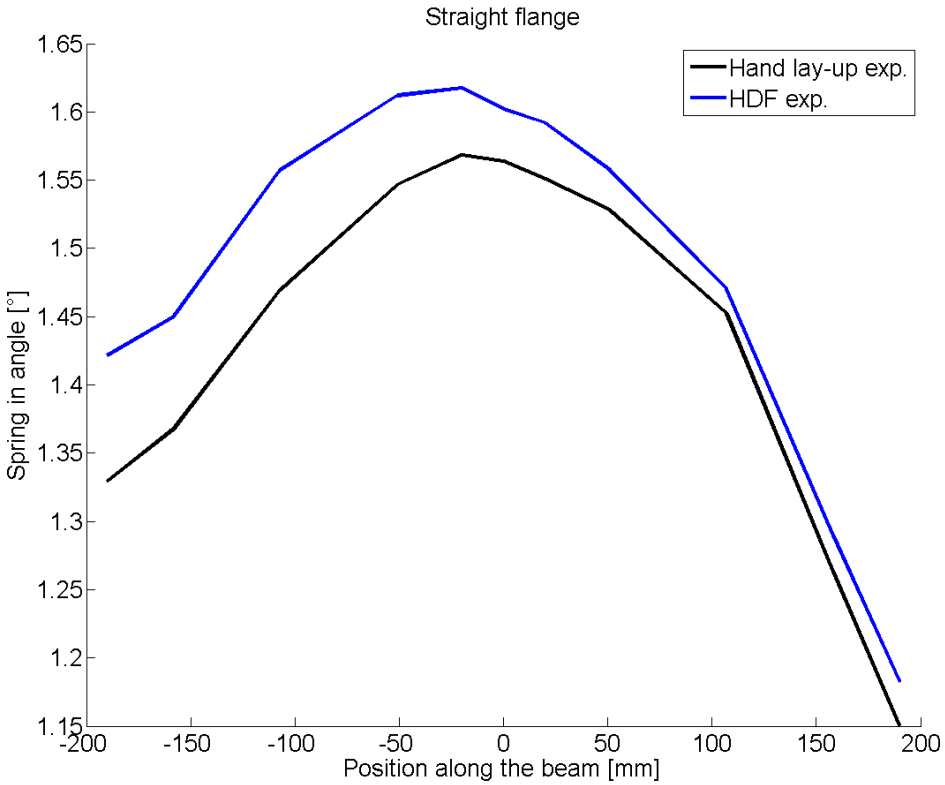


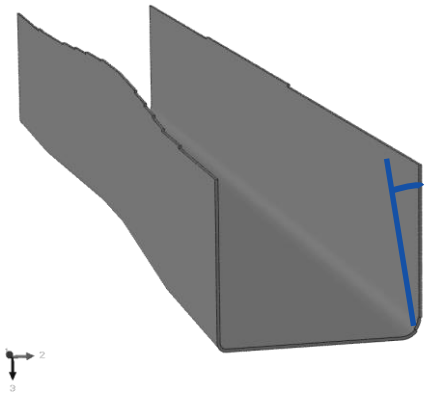
Preliminary simulation results



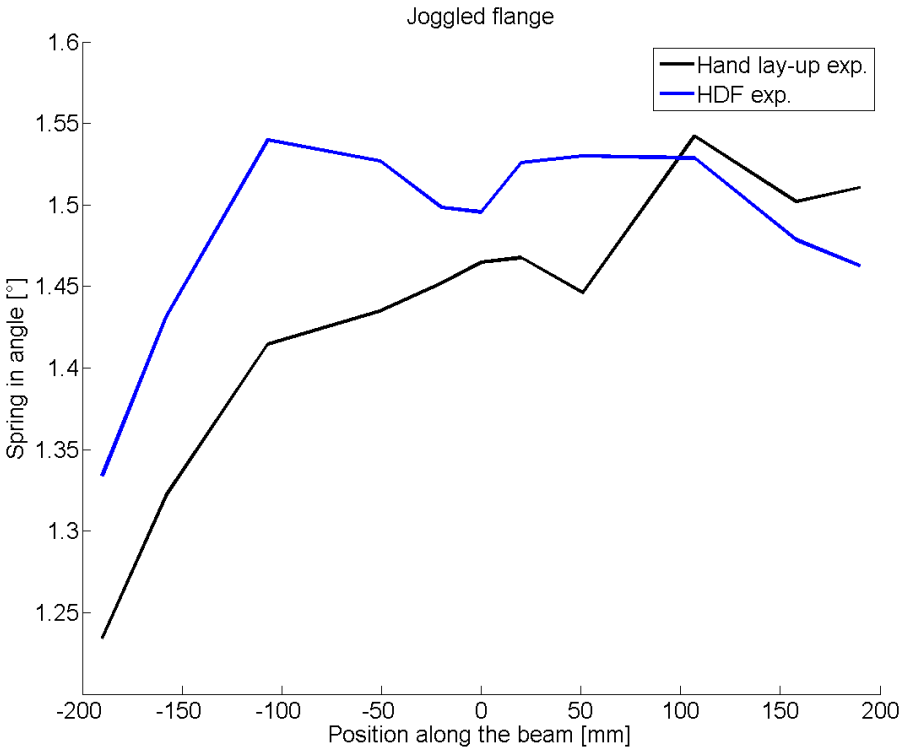


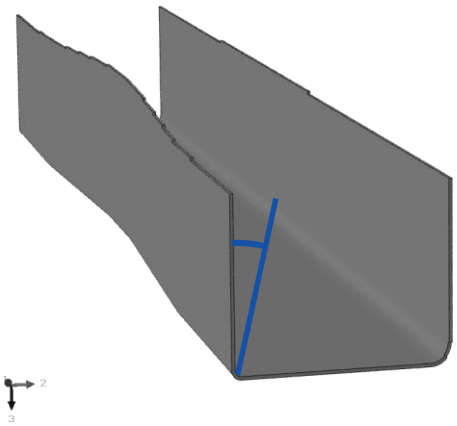
Shape distortion straight flange





Shape distortion joggled flange





Conclusion

There is an effect on geometry from the forming process as well as from the curing process

Especially thickness at the radius seems to be affected

Future work

Characterize material for use in forming simulations

Do shape distortion calculation and compare to new experimental results

Thank you