ADVANCED POST-PROCESSING OF RESULT FROM MOLDFLOW / MOLDEX3D AND EXTENSION

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Assembled warpage, Barycentric coordinate system, moldflow, moldex3d, python

ABSTRACT –
With the development of the industry for light weight, more and more complex reinforced plastic parts are now widely used. The processing software like Moldflow and Moldex3D is commonly used in plastic moulding to simulate the melt flow and defects predictions.

The traditional post processing tools in Moldflow / Moldex3D is designed mainly for user from processing field, it is difficult to solve complex user-defined calculation. Additionally, the best solution for use is to integrate as many as possible into one single platform.

Here the paper introduced 3 typical applications that used ANSA / META to proceed the simulation result from Moldflow / Moldex3D for complex result calculation and approaches. It also can be fully integrated into optimization flow like LS-Opt or Isight.

TECHNICAL PAPER -

1. INTRODUCTION

BetaCAE system was introduced to CAE team in BASF China around 5 years ago, used for as the solution for model preparation and result review with good interface for software like Abaqus, Ls-dyna, Tosca etc. But since there is no direct result interface from Autodesk Moldflow and Coretech Moldflow, we take lots of efforts to unify that two software into unified Betcae pre and post processing platform.

More reason for us to develop the post processing is to use the advanced functions of ANSA & META to solve some complex problems like multiple model compare, feature angle based face selection, complex mathematical function calculation, excel file read & write etc

The major approaches to achieve those targets is by python scripts that integrated inside of ANSA / META.

2. APPROACH OF MOLDFLOW / MOLDEX3D RESULT BY ANSA/META

The python scripts and column text input format could be used for interface development for 3rd party simulation's results.

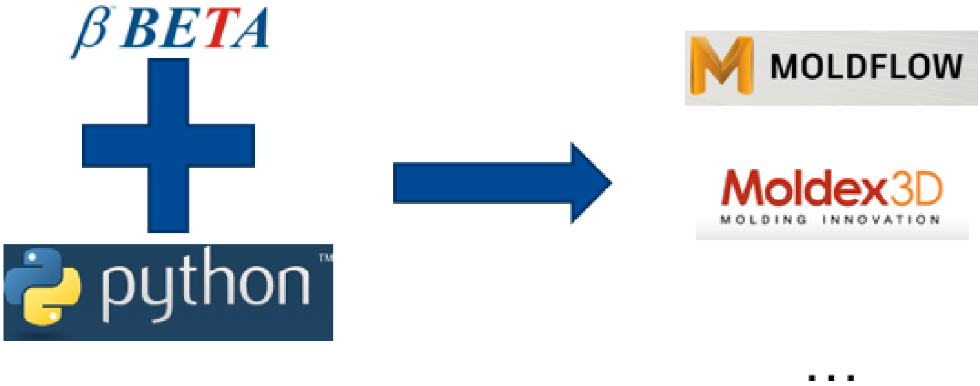


Figure 1 – the link method between BetaCAE and Moldflow/Moldex3D

There are basically two way to make meta understand the 3rd party simulation result which is not in the original supported format：

Solution 1:

Translate the Moldflow or Moldex3d's model file into general FE input file like Nastran or Patran format, and then read the ASCII based result file with necessary calculation and read as result set by python scripts in meta and plot.

Usage: the warpage plot.
Process:

1) Get the warped file from Moldflow in Patran format or any warped output model from Moldex3D
2) Read the original model (Patran from Moldflow or MFE format from Moldex3) into Meta
3) Calculate the node difference of warped model and original model as displacement result
4) Read those calculated value as deformation and scalar result and plot

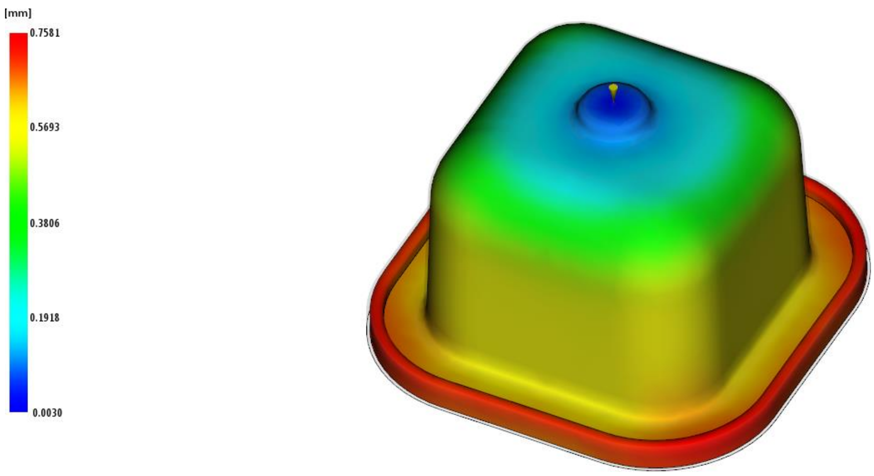


Figure 2a – Warpage Plot in Moldflow

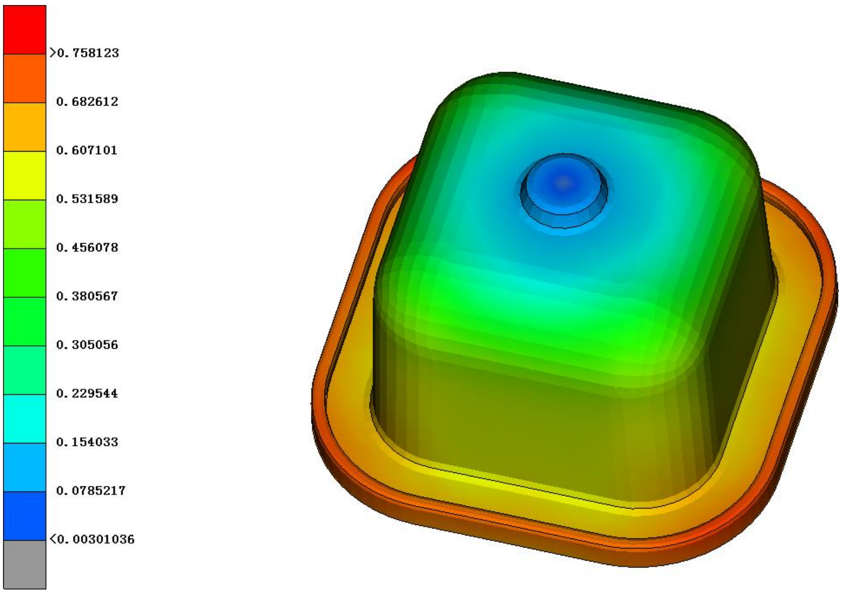


Figure 2b – Warpage Plot in Meta Post

<u>Solution 2:</u>

For some advanced result like fiber orientation, temperature, filling time… Moldflow provide an command line tools to output the result as XML file, we can use the XML interpreter of python read result and process it with numpy for principal value if needed.

Usage: Fiber Orientation, Filling Time
Process:

1) Get the warped file from Moldflow in Patran format
2) Output the interested result with moldflow command line studyrlt with specified result ID
3) Read XML result with python scripts and loaded as scalar result; for vector result, the column ASCII files could be support for vector plot.

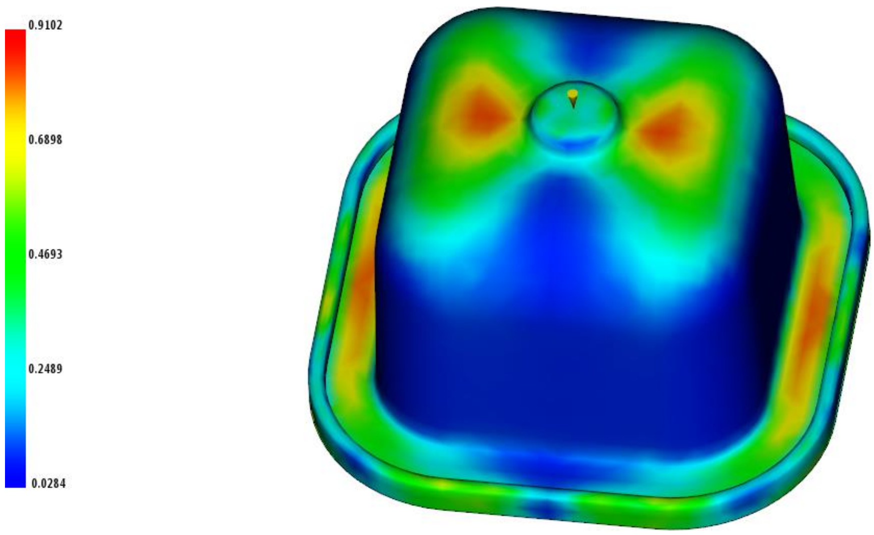


Figure 3a – Fiber Orientation Plot in Moldflow

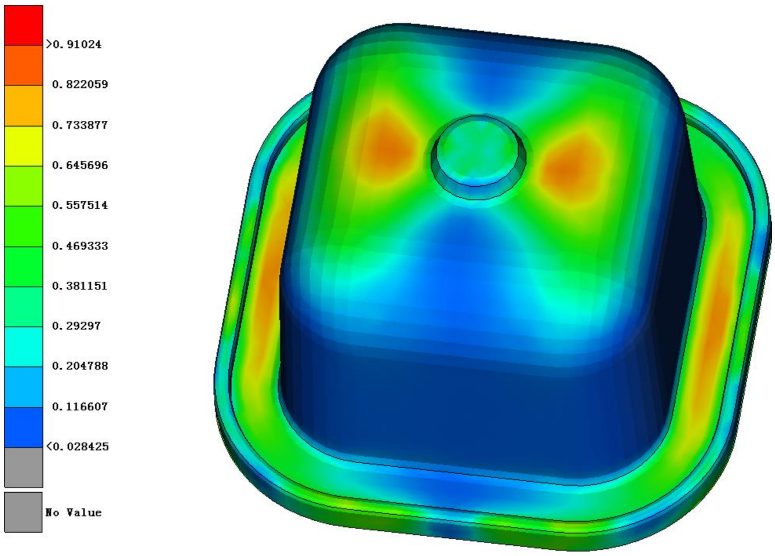


Figure 3b – Fiber Orientation Plot in Meta Post

3. TYPICAL COMPLEX PLOT AND CALCULATION WITH META FOR DATA FROM MOLDFLOW / MOLDEX

3.1 Complex path plot

With more and higher weight reduction request from automotive industry, the fiber reinforced plastic now is widely used for powertrain application. The higher ratio of strength to density bring lots of new parts traditionally by metal now turned into plastic solution. One of those disadvantages of fiber reinforced material is the warpage caused by uninformed shrinkage, especially will cause problem of sealing or welding problems.

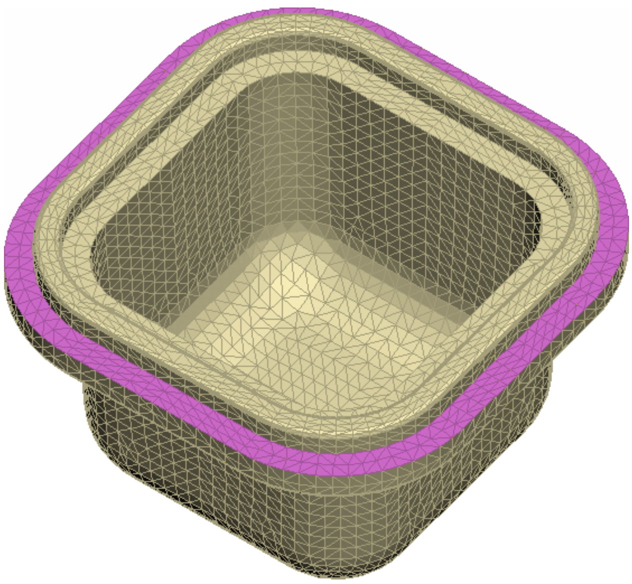


Figure 4 – Highlighted surface for flatness checking

The Figure 4 shows a typical case that need to get the flatness of the highlighted surface in each iteration of processing simulation to find the best scenario of the flat surface. One of the approach would be the make a line plot either inner nodes or outer nodes and calculate the flatness and other output like average value, root square value, standard deviation etc.

The traditional way in Moldflow need to pick all the nodes on the line one by one, it is almost impossible for this case with more than 100 nodes.

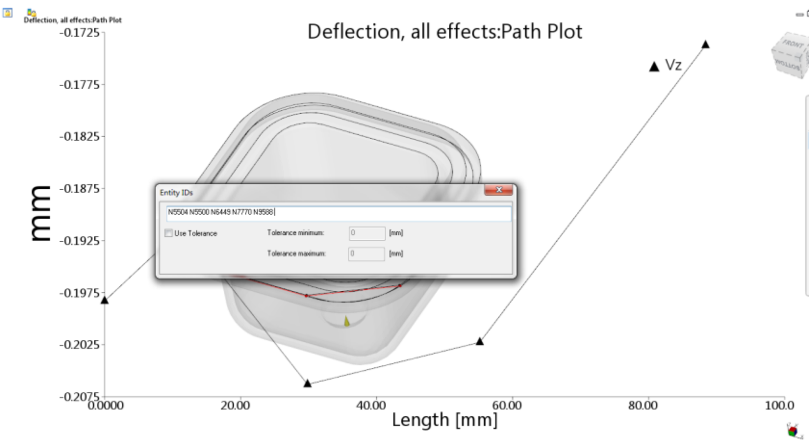


Figure 5 – Path Plot in Moldflow

With stress linearization tools in Meta, only one click with appropriate feature angle based line plot with specified Start point and End

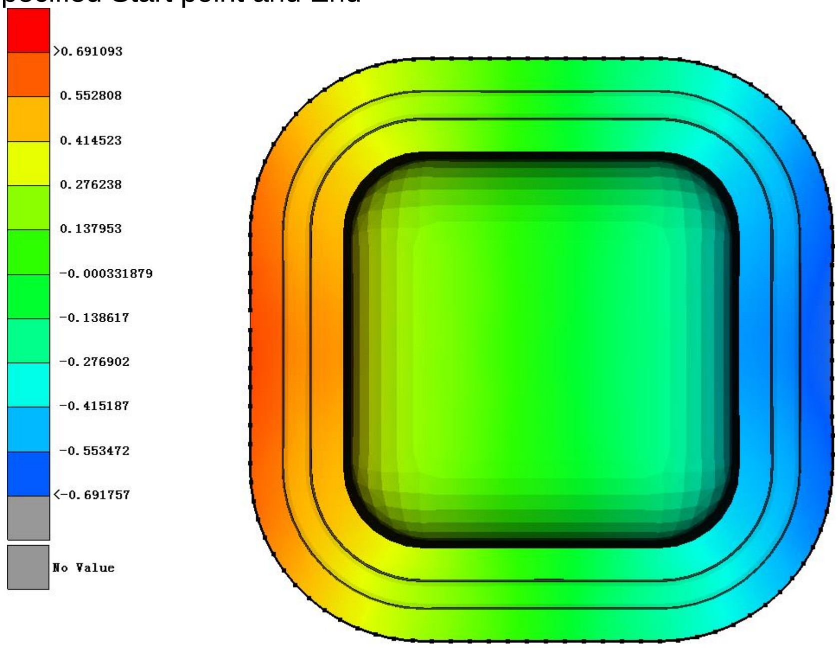


Figure 6a – Nodes selection by feature angle in Meta

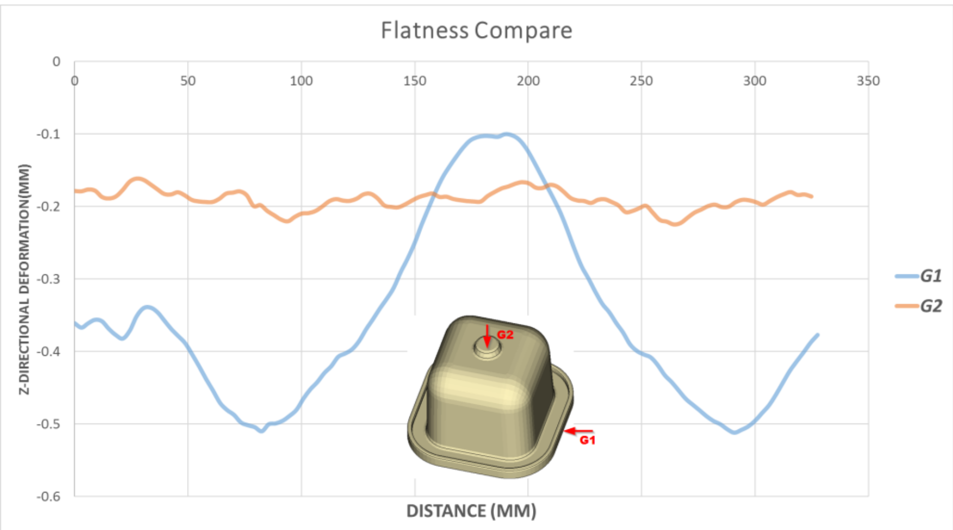


Figure 6b – Z-directional Flatness Compare with different Gate plot in Meta Post

The additional benefits is the operation could be recorded as macro and would be called by optimization tools like LS-opt or Isight to find the optimal values by certain optimization process with best processing parameters.

3.2 Fiber orientation plot through thickness plot used for Correlation

Fiber orientation is one of the key result influence the mechanical behaviour of the fiber reinforced material and affect that anisotropic material property.

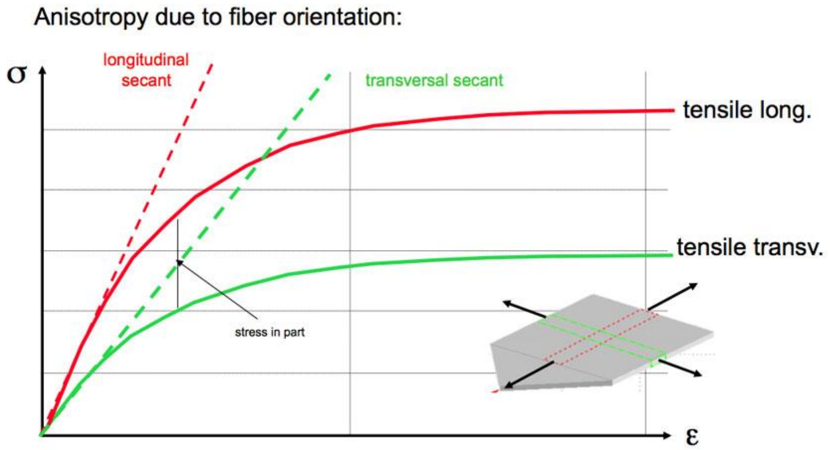


Figure 7a – Material Anisotropy due to fiber Orientation

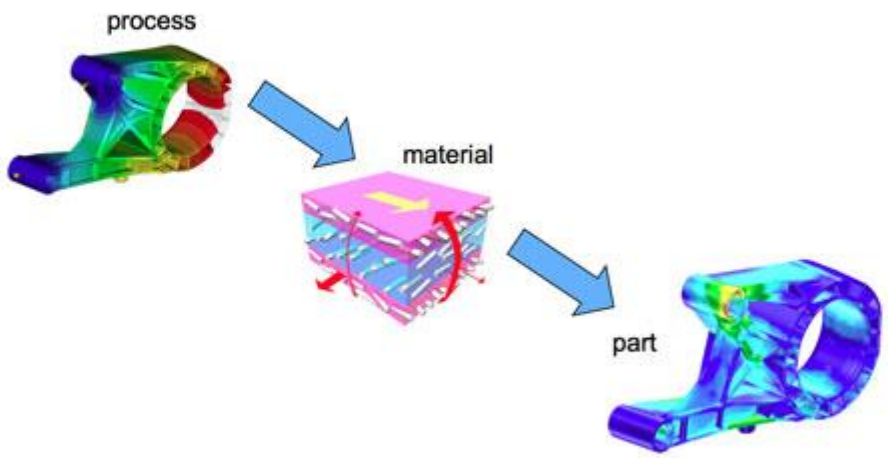


Figure 7b – Material Anisotropy due to fiber Orientation

As figure 7a shows the strong anisotropy of material caused by the processing conditions of the material (including gate locations, flow speed, geometry shape etc). The accuracy of fiber orientation is the key factor to make a good simulation. The best correlation of fiber orientation currently is to compare the simulated fiber orientation tensor (Txx, Tyy and Tzz) with CT measurement.

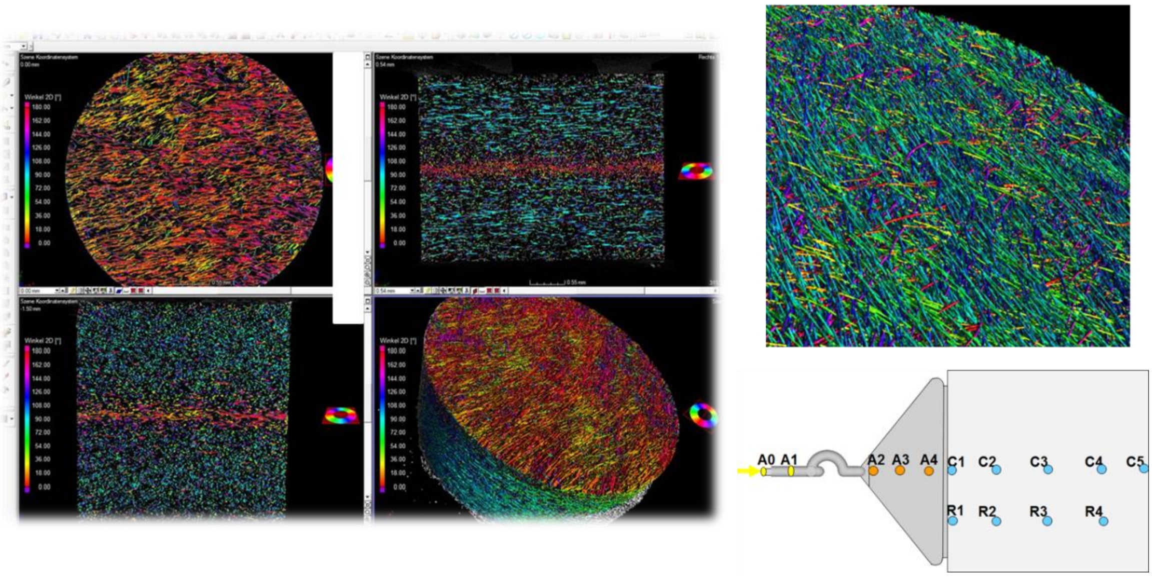


Figure 8 – CT measurement for test specimen

BASF use the test specimen as Figure 8 shows for fiber orientation for several of those measuring points. The raw data from CT measurement will be re-calculated as fiber orientation data and compare with simulation result from Moldflow or Moldex3D like figure 9 shown.

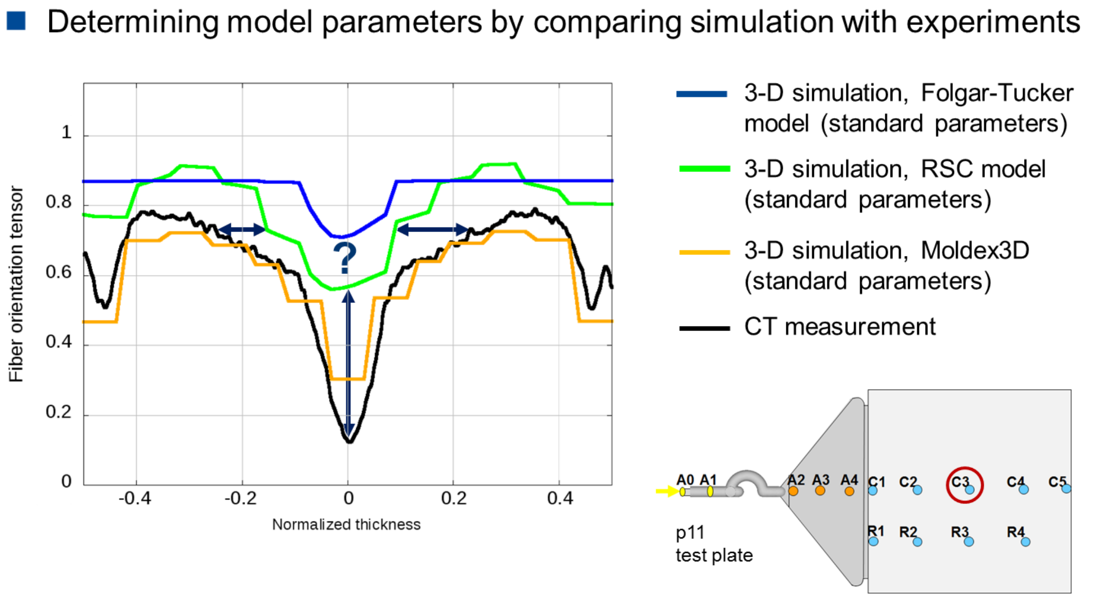


Figure 9 – Correlation result of Fiber Orientation from CT measurement and simulation

Normally Moldflow or Moldex could also plot the fiber orientation within their own post processing tools. One of the limitation of either Moldflow or Moldex3D is the plot position need to be the node position, otherwise the compromised solution would be the nearest node of interesting points. It is not a problem for the part with pre-defined points for measurement, but it need to be either to make compromise of position or redo the simulation with mesh adjustment to get the correct result on right position, sometimes it would get problem for coarse meshed part geometry.

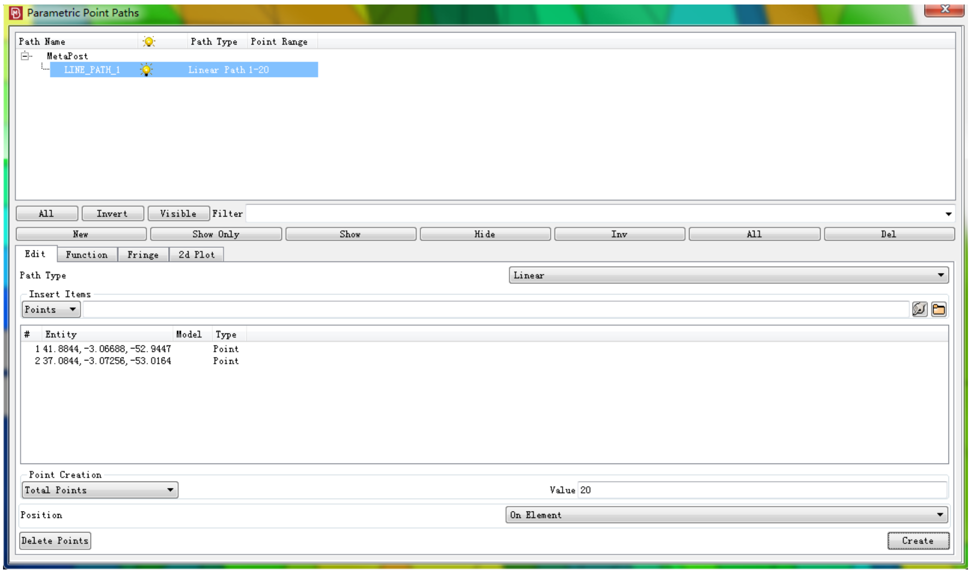


Figure 10 – Stress Linearization tools with linear plot

As figure10 shows the stress linearization tools can be used for fiber orientation plot with specified coordination system and points, the points value could be calculated from interpolated either node result or element integration points result. These tools provide a flexible plot tools for result showing with less effort with redoing simulation.

3.3 Multiple parts assembly clearance checking

With the increasing of complex plastic parts used in the industry, the more and more plastic parts need to be assembled or welded with metal or other plastic parts. The traditional warpage prediction based on single parts sometimes does not work or even lead to wrong direction.

For example:

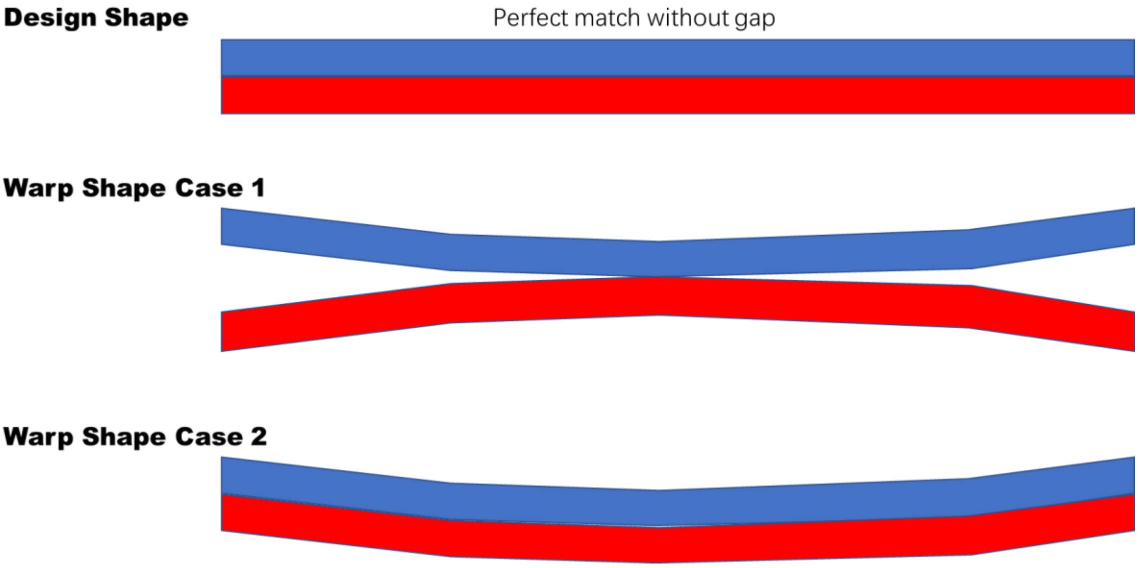


Figure 11 – warpage situation for assembly

As figure 11 shows, the actual part after production would generate different states of situation for assembly. Like warp case1, the both part warp in totally opposite direction will cause big trouble in assembly or welding. The warpage criteria based on single part cannot predict those problems and we also need to quantify the gap and could be precisely control the assembly or welding process.

The difficulty of quantify the gap value is both reference is not fixed and traditional coordination system is not working to consider the gap quantity in two components.

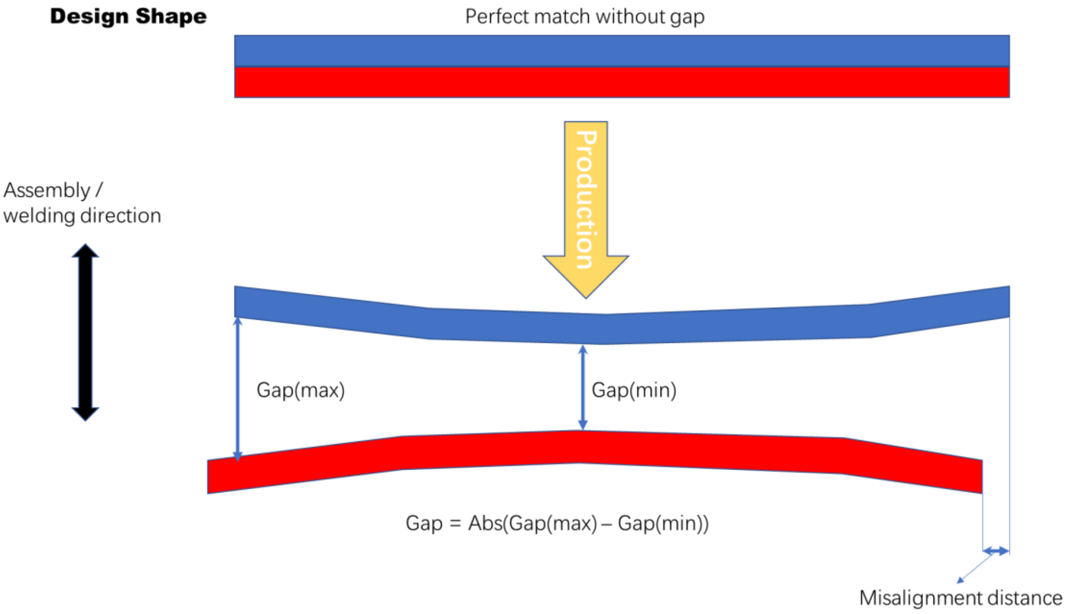


Figure 12 – warpage situation for assembly

To solve those problems, we would like to import the Barycentric interpolation method to find the way to calculate the right value. Since for most of engineering problems, we use the tetra or penta (prism) mesh for processing simulation, the triangle surface is the key to get the answer.

Barycentric interpolation on triangles:

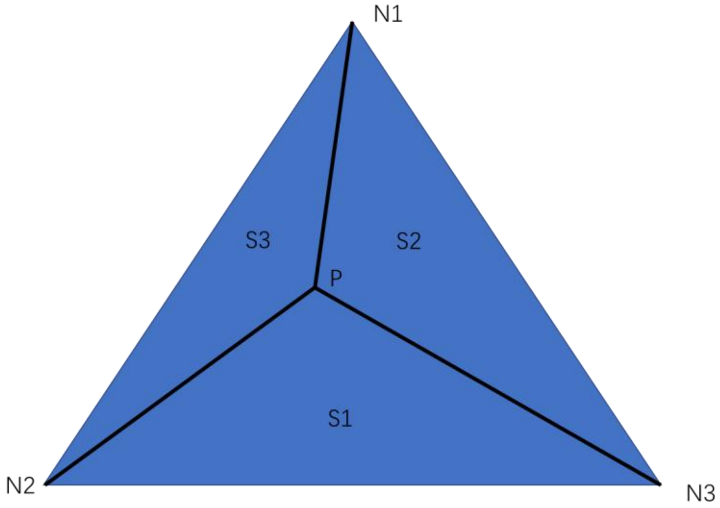


Figure 13 – Barycentric interpolation method

If we assume there is one point P in side of triangle N1N2N3:

$$\lambda_1 = S1/S; \lambda_2 = S2/S\ ; \lambda_3 = S3/S$$

$$\lambda_1 + \lambda_2 + \lambda_3 = 1$$

For triangle, λ1~3 can be used to describe the P’s relative position inside of triangle whenever the triangle shape changes, we can convert the Barycentric coordinates back to Cartesian coordinates:

$$P = N2 + \lambda1 * \overrightarrow{N3N2} + \lambda3 * \overrightarrow{N1N2}$$
Or
$$P = N1 + \lambda2 * \overrightarrow{N3N1} + \lambda3 * \overrightarrow{N2N1}$$
Or
$$P = N3 + \lambda1 * \overrightarrow{N2N3} + \lambda2 * \overrightarrow{N1N3}$$

While, if we want to judge whether the point is inside of the triangle, we can also use the judgement as:

$$\lambda_1 + \lambda_2 + \lambda_3 = 1 \text{ and } \lambda_1 \geq 0;\ \lambda_2 \geq 0;\ \lambda_3 \geq 0$$

For special case, if $\lambda_i = 0$, that means the points is located on the edge of the triangle.

With this Barycentric interpolation method and coordinates, we can establish a flow chart to calculate the assembly gap and misalignment distance.

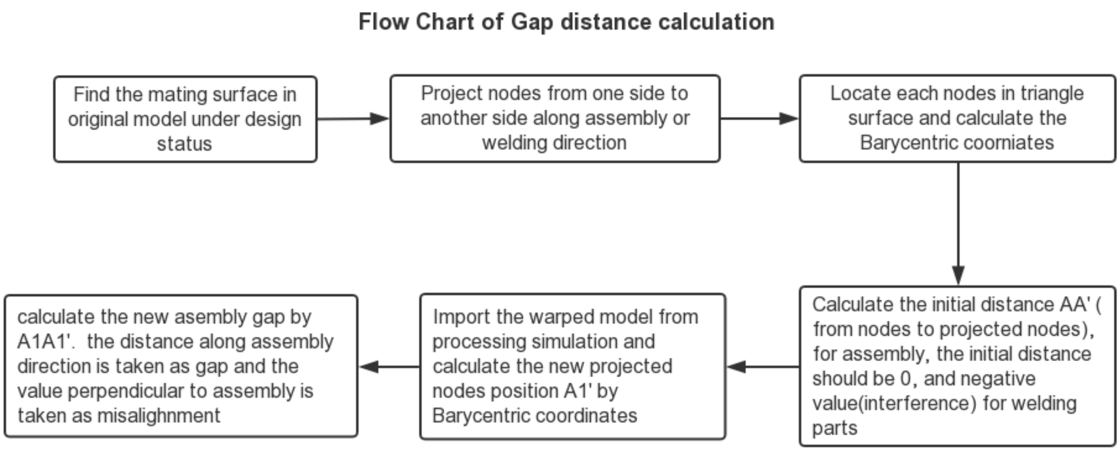


Figure 14 – Flow chart to calculate the gap and misalignment distance

To achieve this process flow, we need the python scripts integrated both in ANSA and Meta, also with help of numpy, the vector calculation would be much easier to implement.

The key process that can achieved by ANSA/Meta Scripts

a) Project nodes into triangle:
“ansa.calc.ProjectPointToTriangle” could be used for projecting node into specified triangle mesh and output whether the points is inside or outside of the triangle.

b) Calculate the u,v of points inside of triangle:
For triangle in 2d plane, we can simplify Barycentre coordinates into u,v expression.

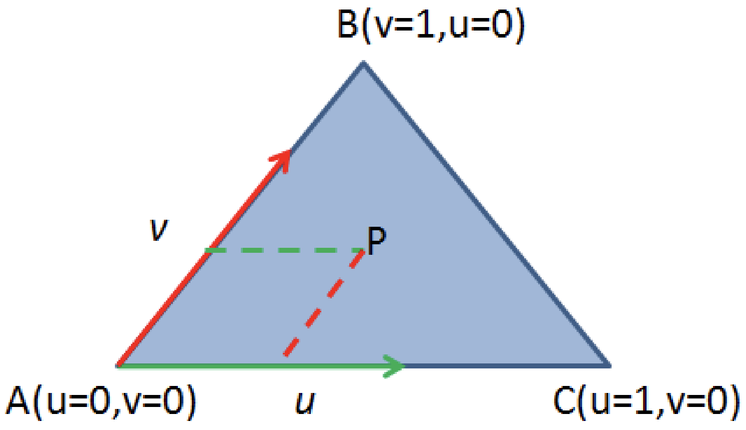


Figure 15 – u, v expression of Point P inside of Triangle ABC

Point P can be calculated as:

$$P = A + u * (C - A) + v * (B - A)$$

Change the P expression as:

$$P - A = u * (C - A) + v * (B - A)$$

We can define 3 vector as below:

$$v0 = C - A$$
$$v1 = B - A$$
$$v2 = P - A$$

So, we can infer:

$$v2 = u * (C - A) + v * (B - A)$$

As there is only one equation with 2 unknown u,v, we can’t solve this equation. We multiple by both side with V0 and V1:

$$v2 \bullet v0 = (u * v0 + v * v1) \bullet v0$$
$$\&$$
$$v2 \bullet v1 = (u * v0 + v * v1) \bullet v1$$

No we can solve the equation:

$$u = ((v1\bullet v1)(v2\bullet v0)-(v1\bullet v0)(v2\bullet v1)) / ((v0\bullet v0)(v1\bullet v1) - (v0\bullet v1)(v1\bullet v0))$$
$$v = ((v0\bullet v0)(v2\bullet v1)-(v0\bullet v1)(v2\bullet v0)) / ((v0\bullet v0)(v1\bullet v1) - (v0\bullet v1)(v1\bullet v0))$$

In ANSA, it is easy to use numpy to build the array and solve the u and v

c) Calculate the P’ position in warped triangle A’B’C’

Read the warped mesh model by same node number with new coordinates value and recalculate the P’ coordinates value by:

$$P' = A' + u * (C' - A') + v * (B' - A')$$

In this paper, we will use the vibration welding specimen to illustrate the process of the assembly gap calculation.

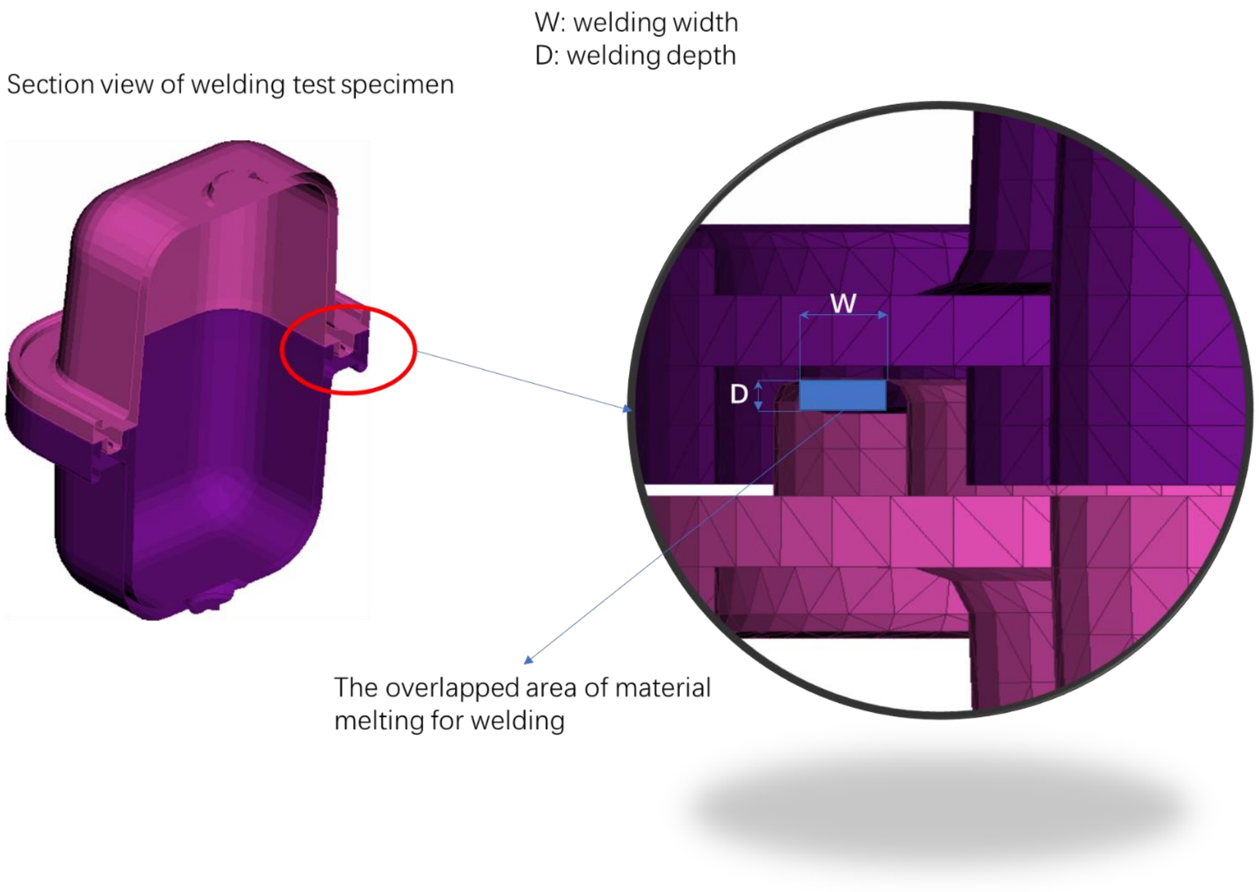
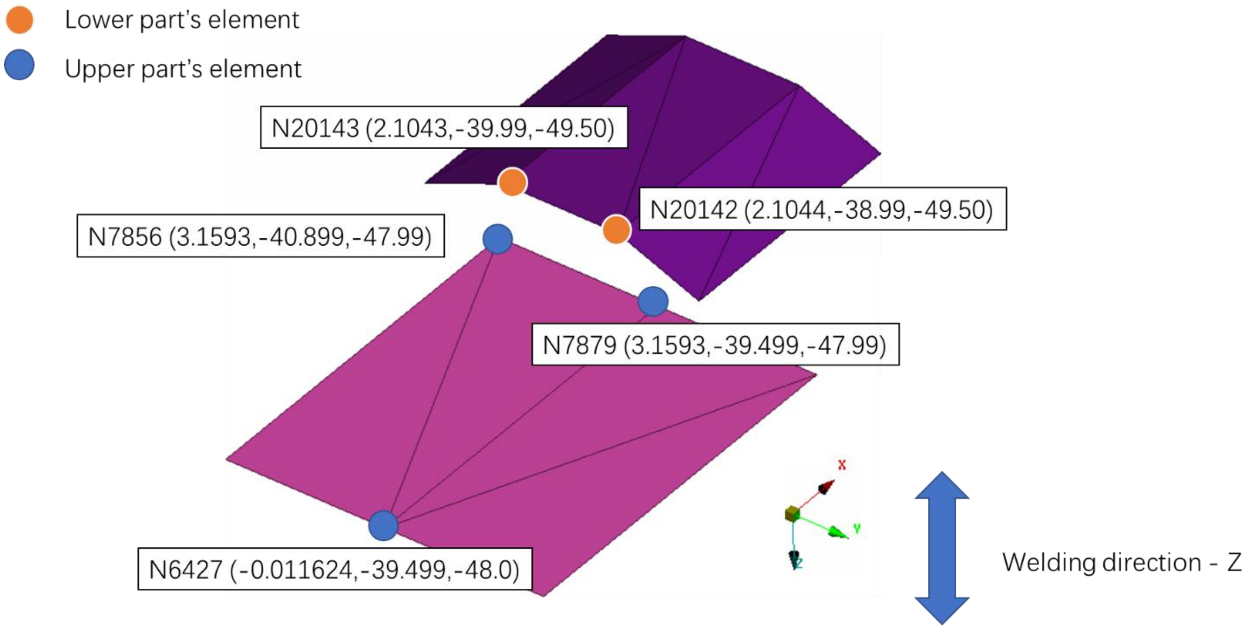


Figure 16 – Plastic vibration welding test specimen

The gap distance here could be calculated as Depth and the real welding width could be calculated as : designed width – misalignment distance

Here we will use two elements between to illustrate how to process this process:



*notice: for welding parts, the lower parts should penetrate into upper parts to represent the welding melt area

Figure 17 – the demo of the gap distance calculation

1) Project the nodes from lower part to triangle(N7856N7879 N6427) from upper parts and find the right mapping points and u, v value.

   Utilize the function of “ansa.calc.ProjectPointToTriangle”, if the return length is 1 and not “0”, then the point can be projected inside of triangle. The N20143 could be found projected inside of triangle (N7856N7879 N6427)

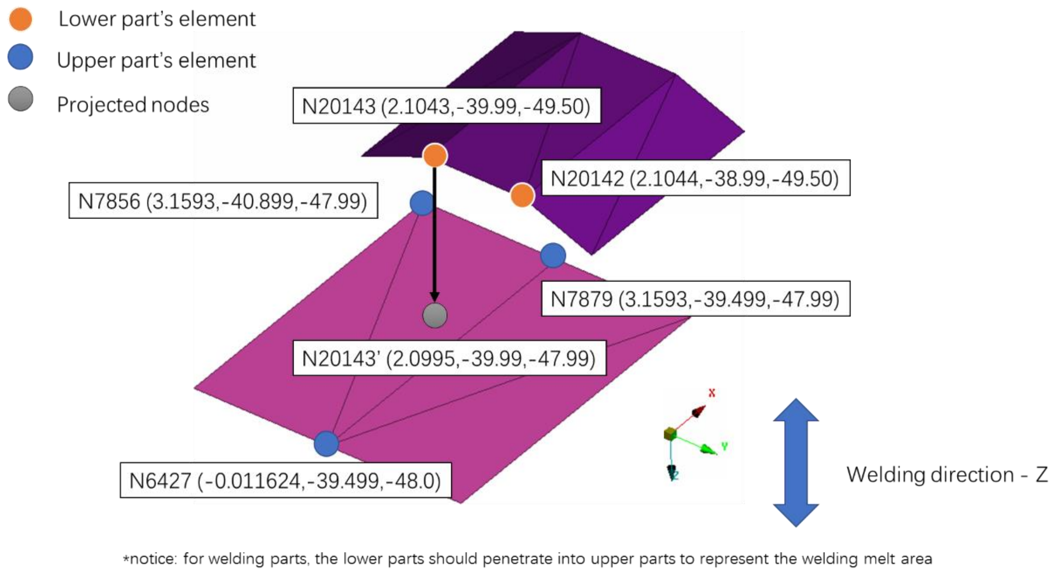


Figure 18 – Find projected nodes inside of triangle

The calculated u&v value of N20143’ in triangle (N7856N7879 N6427) is:
u = 0.3342; v = 0.3150

2) Read those nodes coordinates in new warped model

   Read the nodes from warped model and recalculate the projected nodes from u,v value based on last calculation:

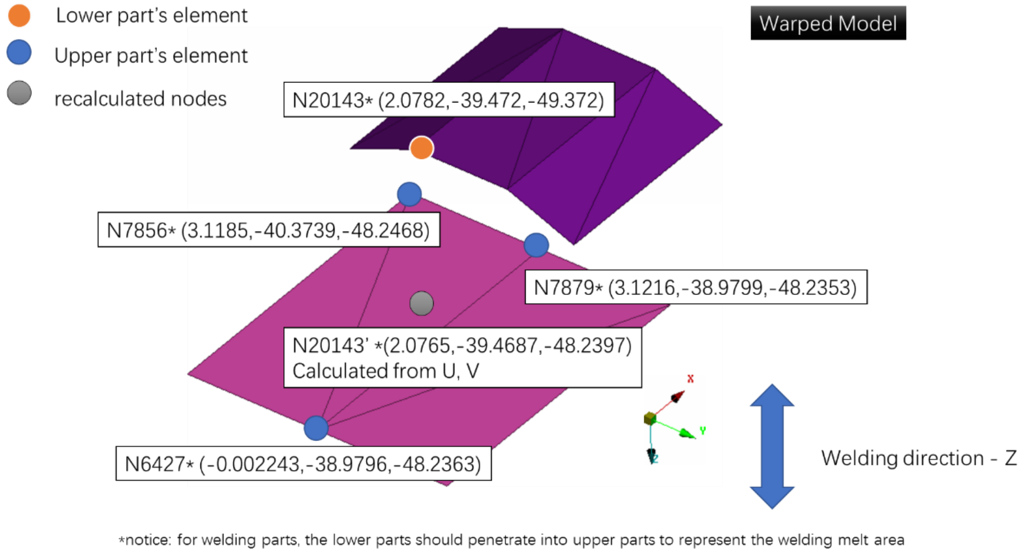


Figure 19 – calculated projected nodes new position in warped model

3) Calculate the Depth and misalignment displacement:
   Depth of original = 1.51
   Depth of warped = 1.1323
   Misalignment distance = 0.0042

Per this method, all nodes mated for welding could be calculated and find the lowest depth for criteria to compare with different processing conditions to find the best solution.

This method also could be called by optimization programme to find the best solution based on optimization algorithm.

4. CONCLUSION & OUTLOOK

The python scripts expansion in ANSA and META provide user flexible solution to deal with complex calculation and deal with the user-defined solver or software still not officially supported. The further integration of numpy could simplify lots of mathematical calculation function for matrix calculation. We also hope it could integrate more python library like scipy and matplotlib for stronger calculation functions.

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