Colombia mar2019

VI CONGRESO INTERNACIONAL DE DISEÑO E INGENIERÍA NAVAL

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A Practical Analysis of the Influence of Tool Positioning During High-Frequency Mechanical Impact Treatment on a Welded Joint

Un Análisis Práctico de la Influencia del Posicionamiento de la Herramienta durante el Tratamiento de Impacto Mecánico de Alta-Frecuencia

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**Zoartech Consulting, Panama

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Outline

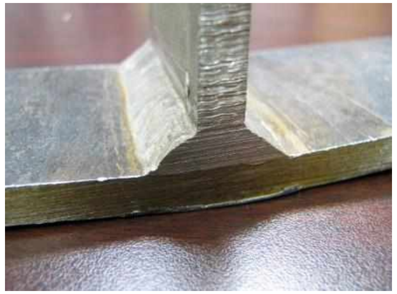
Background of the Study

Problems

Fatigue life of welded structures is affected due to

- Residual Stresses
- Material Hardening/softening
- Crack Propagation

Butt welded joint



T-butt welded joint

Tubular welded joint

One Solution

Improve the fatigue strength of welded structures by Mechanical Impact Treatment.

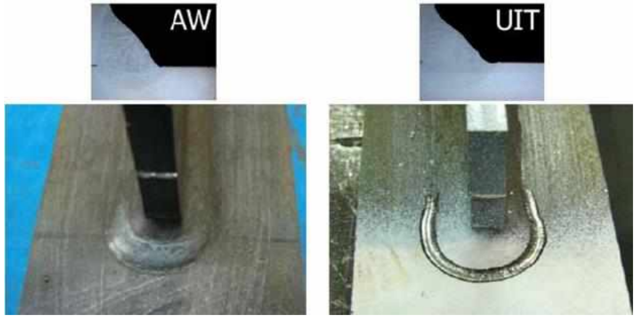
Reliable prediction of the effect of High Frequency Mechanical Impact Treatment (HFMI).

High Frequency Mechanical Impact (HFMI)

- In 2010 IIW Commission XIII coined the term HFMI, as a generic term to describe several related technologies for improving the fatigue strength by locally modifying the residual stress state.
- HFMI makes use of cylindrical indenters which are accelerated (> 90Hz).
- The impacted material is highly plastically deformed in the weld toe geometry.
- Improvement of residual stresses, local work hardening and reduction of notch at weld toe.

Pneumatic gun for impact treatment

**IIW Recommendation of Post Weld Fatigue Life Improvement of Steel and Aluminum Structures*



Comparison as-welded and after HFMI

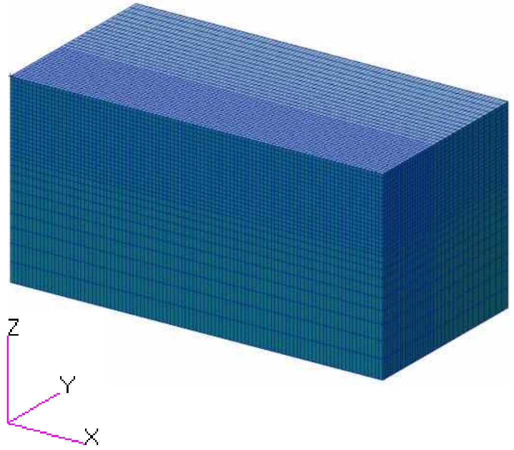
**Welding in the world, Le Soudage Dans Le Monde 57(6)*

Flat Stress-Free Plate Model

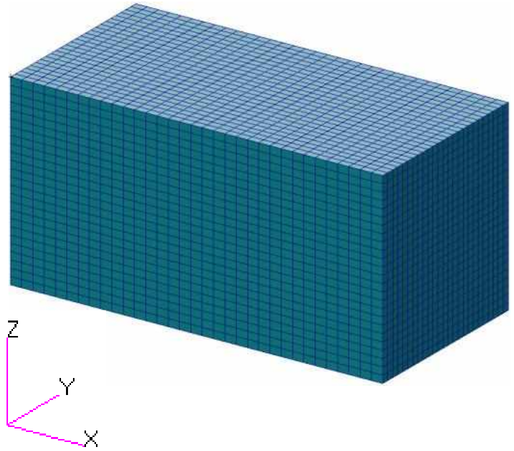
- Dr. Farajian [1] performed several HFMI experiments using a flat plate. They focused on the effect of HFMI close to the surface.
- In their study they compared numerical results with experimental data.

[1] <u>Farajian et al.,2016. High frequency mechanical impact treatment (HFMI) for the fatigue improvement: numerical and experimental investigations to describe the condition in the surface layer.</u>

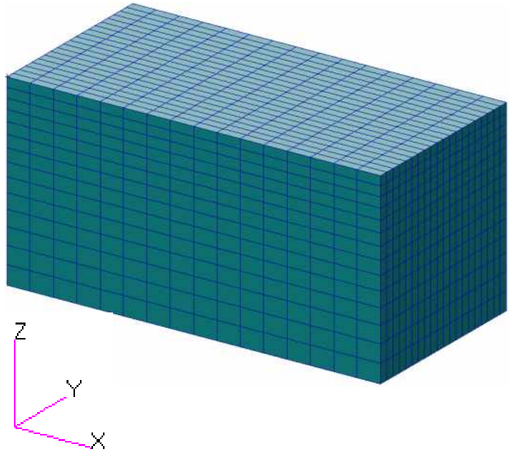
FINE MODEL
Finest Elm size: 0.2x0.2x0.2mm



INTERMEDIATE MODEL
Finest Elm size: 0.6x0.4x0.4mm

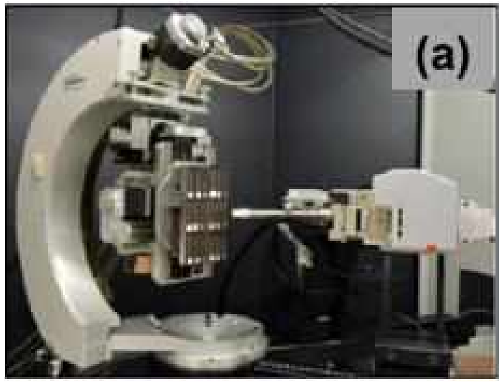


COARSE MODEL
Finest Elm size: 1.25x0.5x0.5mm

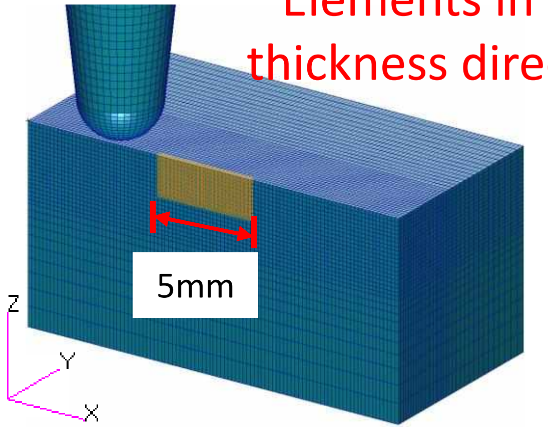


[2] <u>Ruiz et al.,2018. Stability of Compressive Residual Stress Introduced by HFMI Technique[OMAE2018-77887]</u>.

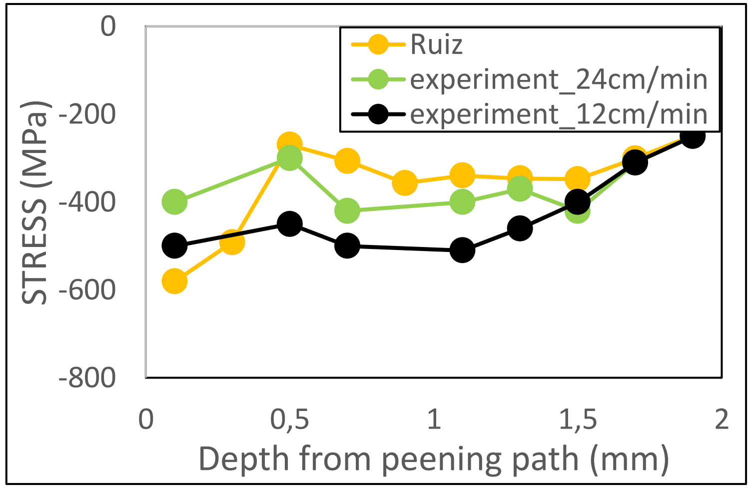
Specimens Treated



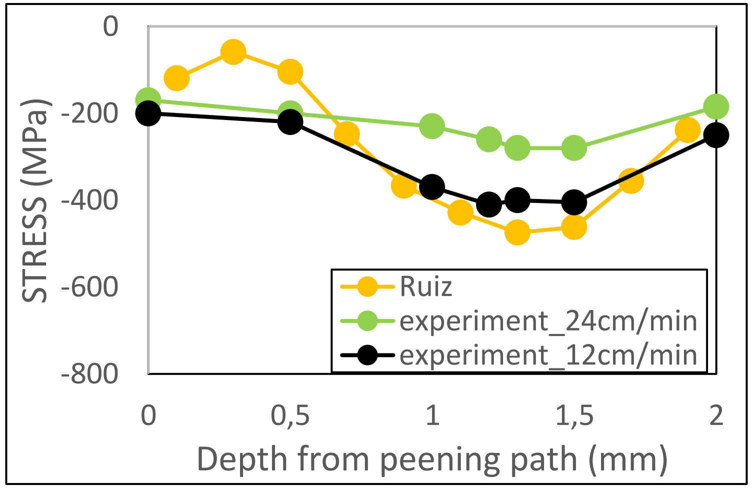
Residual Stress Measurement



[1] Experimental figures shown in Farajian et al., 2016



S_{XX} Residual Stress



S_{YY} Residual Stress

*Experimental results shown in Farajian et al. 2016, numerical results shown in Ruiz et al.2018.

Objective

Different researchers have been investigating the HFMI-process.
Recently, explicit elastic-plastic finite element code was utilized in order to take into account dynamic effect. Also, the effect of finite element mesh and various parameters (e.g., friction coefficient, tool indentations, boundary conditions, etc.) have been examined.
However, recommendations on tool positioning has not been presented yet.

- ***This study focuses on establishing a practical analysis of compressive residual stresses induced by HFMI-treatment using a stress-free model, with different tool angles and impact positions at the weld toe.***

In previous study Ruiz (2018) used the explicit commercial code MSC. Dytran, same software and conditions are considered in this study.

Kinematic Hardening Material

Chaboche's Kinematic Hardening Law:

$$J_2\,(\sigma - \boldsymbol{\alpha}) = \sigma_o$$

$\boldsymbol{\alpha}$: back stress tensor

σ_o: yield stress

Back Stress tensor :

$$d\boldsymbol{\alpha} = \sum_{i=1}^{M} d\boldsymbol{\alpha}_i\,;\; d\boldsymbol{\alpha}_i = C_i \frac{d\varepsilon^p}{\sigma_o}(\boldsymbol{\sigma} - \boldsymbol{\alpha}) - \gamma_i \boldsymbol{\alpha}_i d\varepsilon^p$$

C_i, γ_i : material parameters.

$d\varepsilon^p$: accumulated equivalent plastic strain increment.

M : number of kinematic hardening components. (M = 2 is used in this study)

i : component number.

Yield Stress is given by:

$$\sigma_o = \sigma_{o,0}\,\mathcal{F}(\dot{\varepsilon}^p)\mathcal{G}(\varepsilon^p)$$

$$\mathcal{F}(\dot{\varepsilon}^p) = 1 + (\dot{\varepsilon}^p/H)^{1/\rho}$$

$$\mathcal{G}(\varepsilon^p) = 1 + a\,(\varepsilon^p)^b$$

$\sigma_{o,0}$: initial yield stress.
$\mathcal{F}$: Cowper-Symonds strain rate function
$\mathcal{G}$: Jonson-Cook strain hardening Function.
H , ρ : Cowper-Symonds strain hardening parameters.
a , b : are isotropic strain hardening parameters.

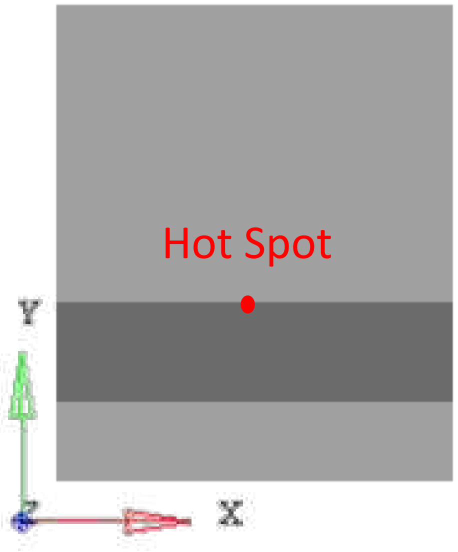
E [GPa]	n	σ_o [MPa]	C1 [MPa]	γ1	C2 [MPa]	γ2
210	0.3	435	8971.8	218.65	12654.88	106.98

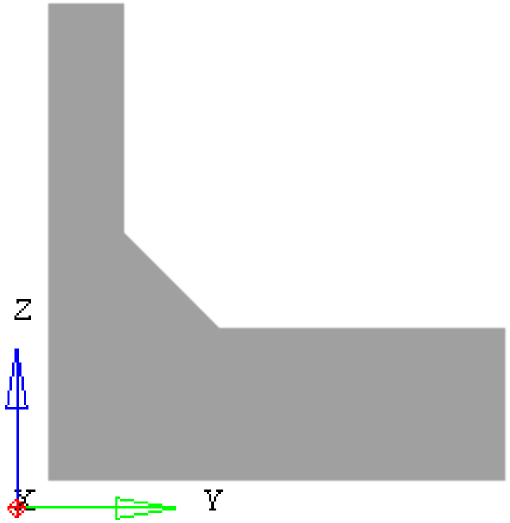
***Material Parameter in ABAQUS for S355J2H (kinematic hardening)**

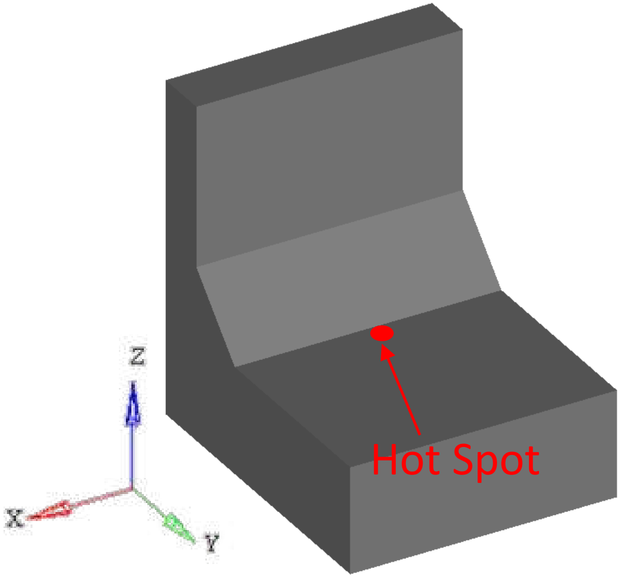
Stress-Free Model

Material	Attachment Length x Height x Thickness [mm]	Plate Thickness [mm]	Width [mm]
S355	20 x 17 x 4	5	24

- ✓ This study analyzes the HFMI-induced residual stresses on the stress-free model.
- ✓ The simulation target is a L-Joint welded specimen shown below.



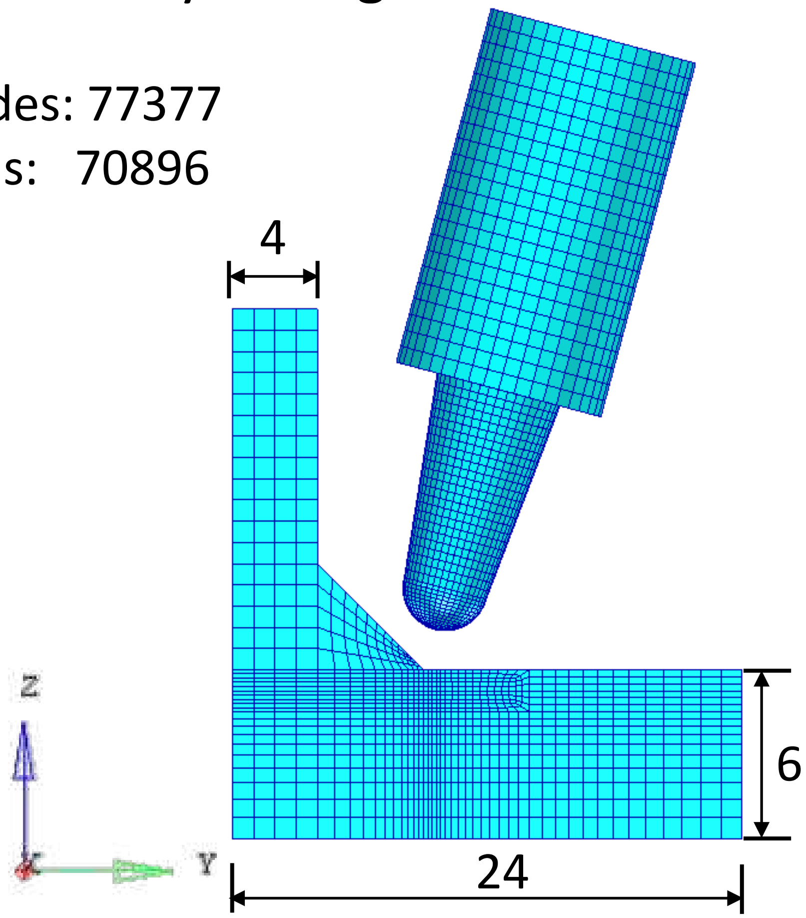


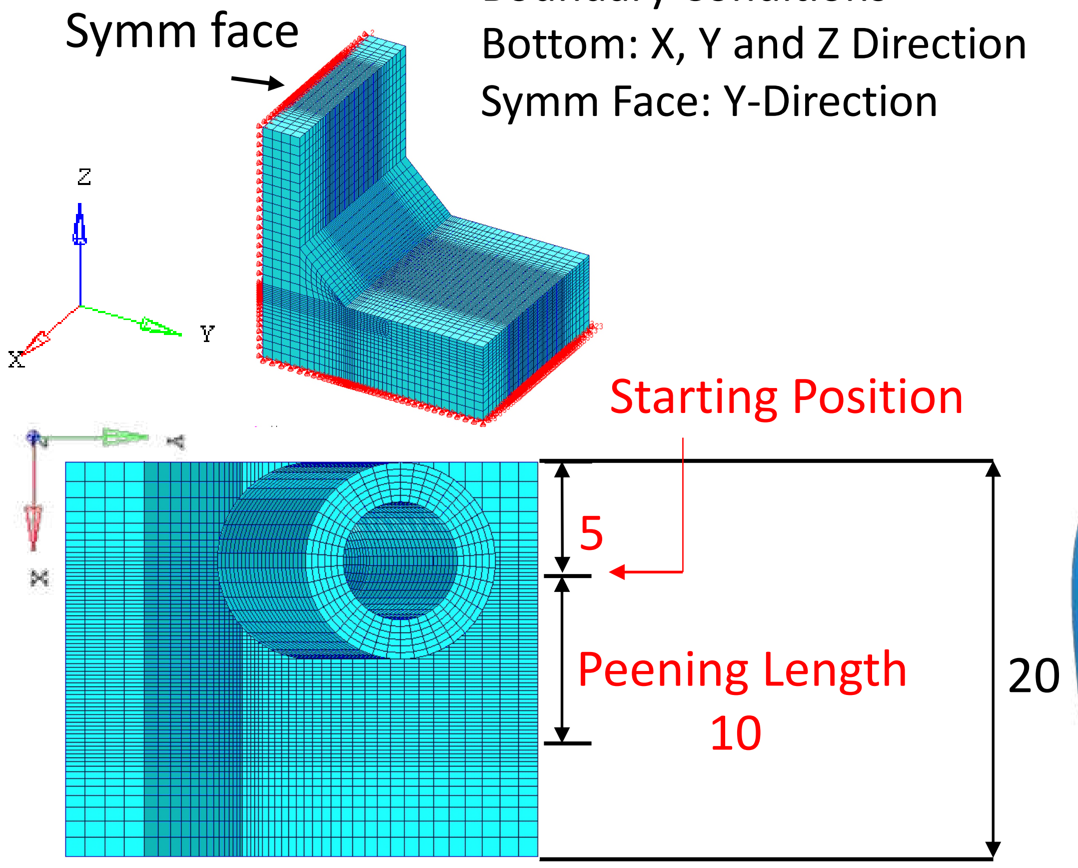


FE Model & Boundary Conditions

- ✓ FE model is built of hexahedron brick elements.
- ✓ The analysis target is modeled half-symmetrical.

Nodes: 77377
Elms: 70896



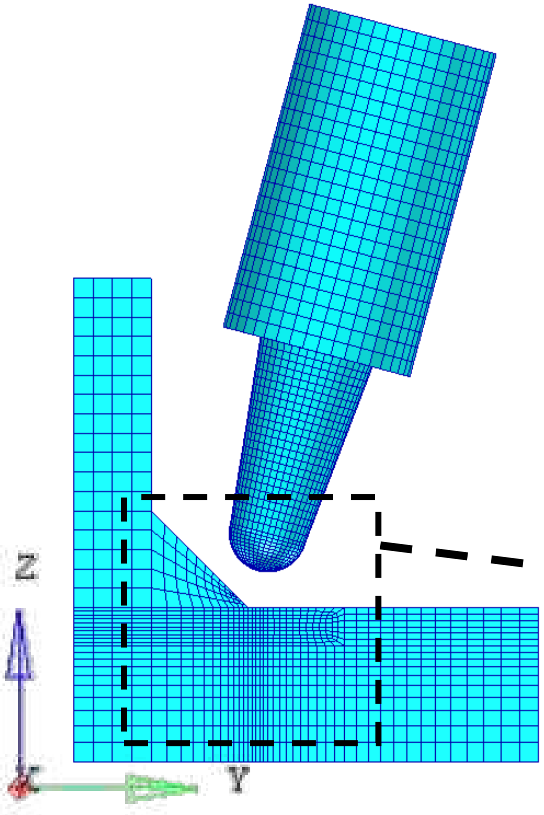


Units in mm

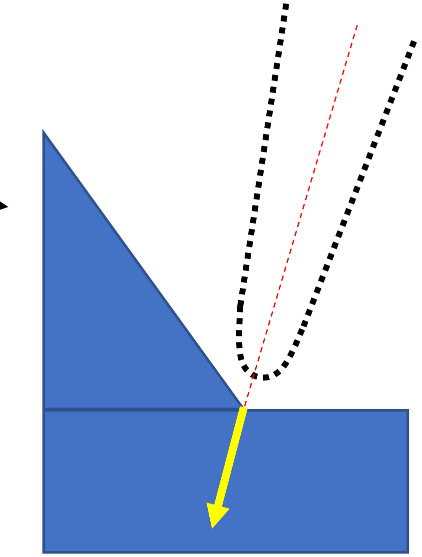
HFMI-Numerical Procedure & Analysis Conditions

Numerical Procedure

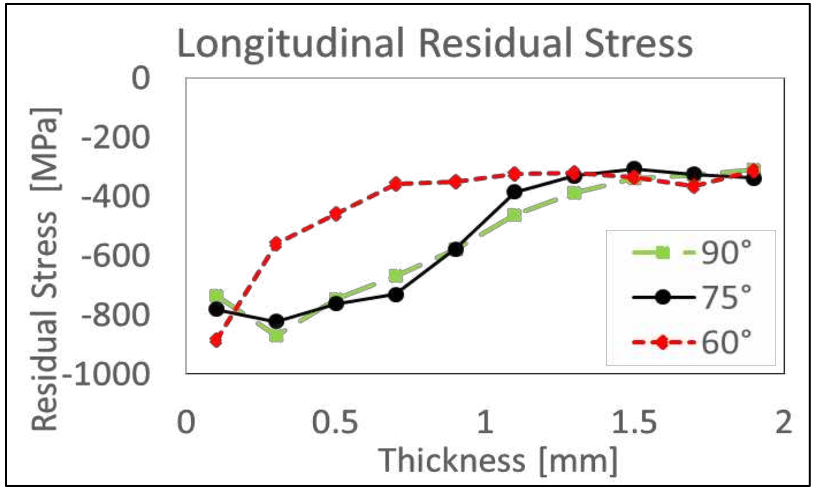
- HFMI-treatment is simulated using MSC. Dytran.
- Displacement Control Simulation (DCS) is implemented.
- Strain rate is not considered.
- Pure Kinematic hardening material is considered

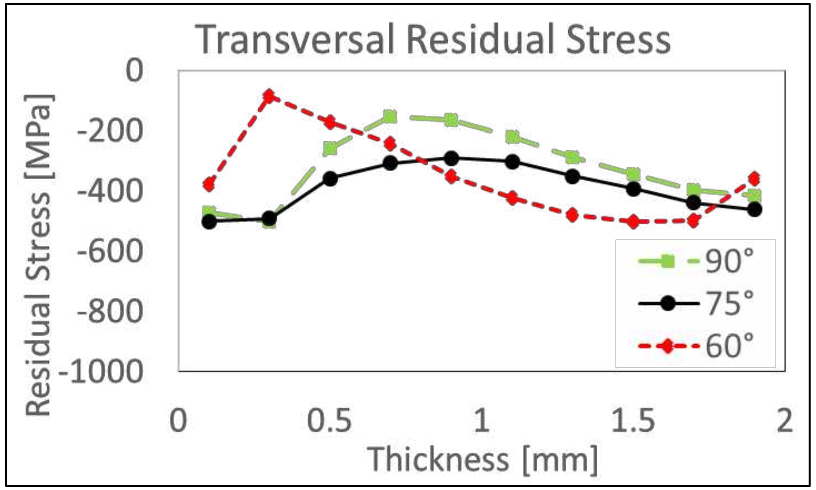


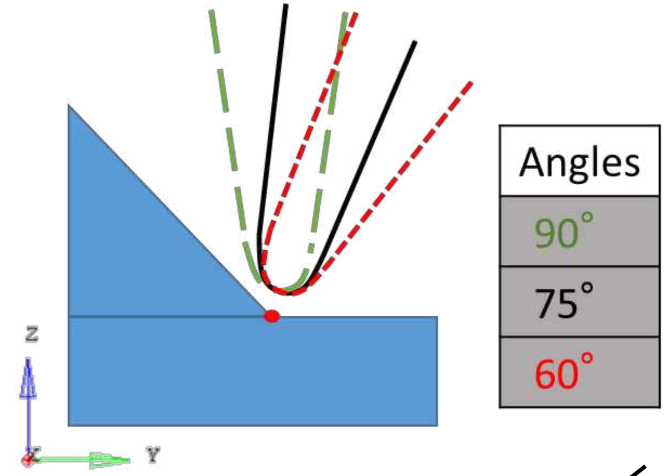
Peening Parameters	
Length [mm]	10
Indentation [mm]	0.2
Pitch [mm]	0.4
Frequency [Hz]	100



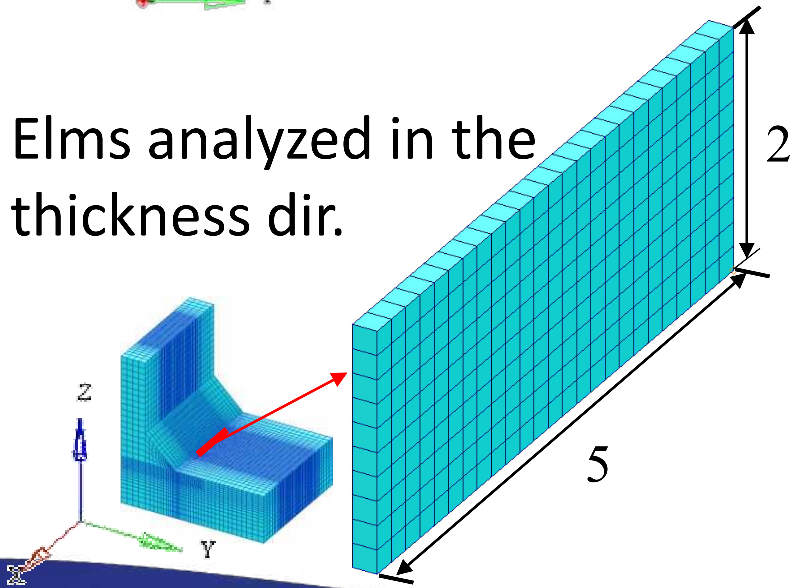
Peening Response due to Tool Angle



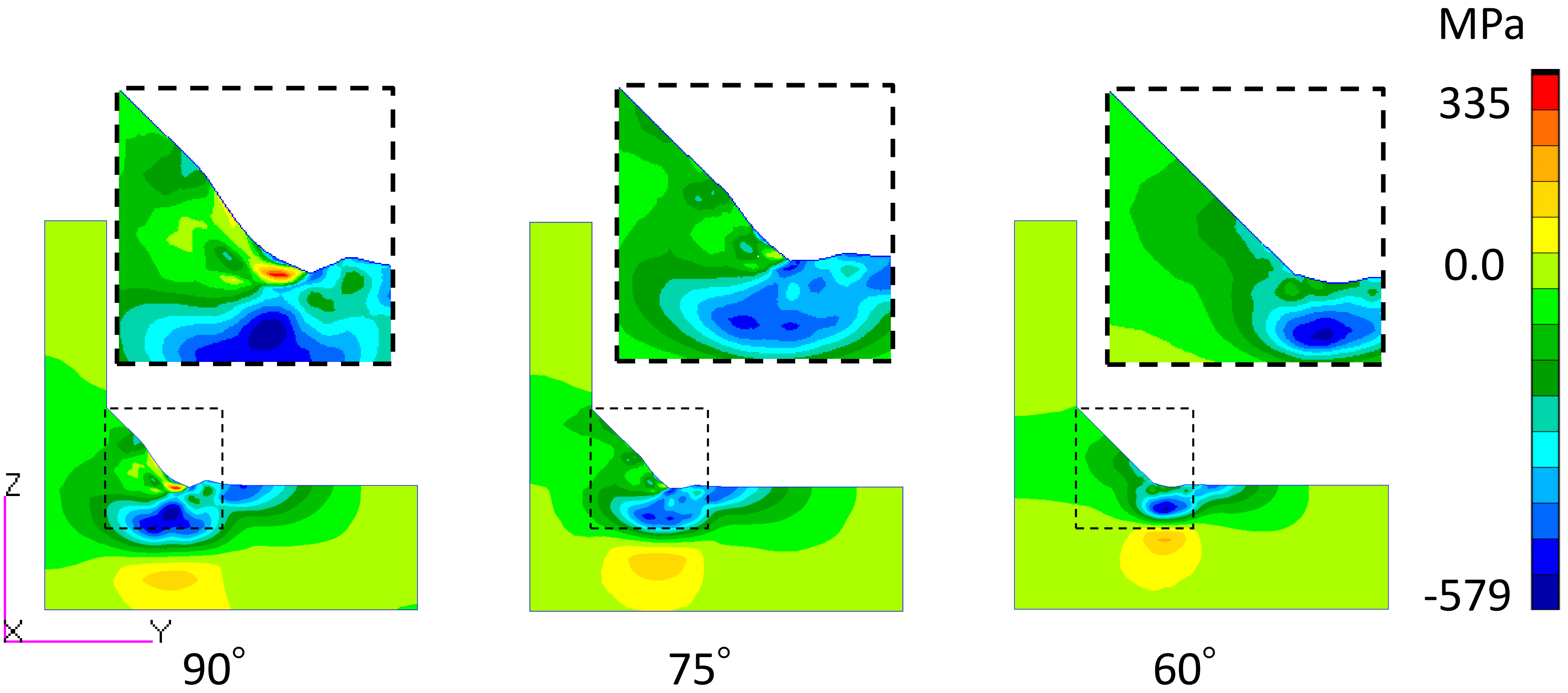




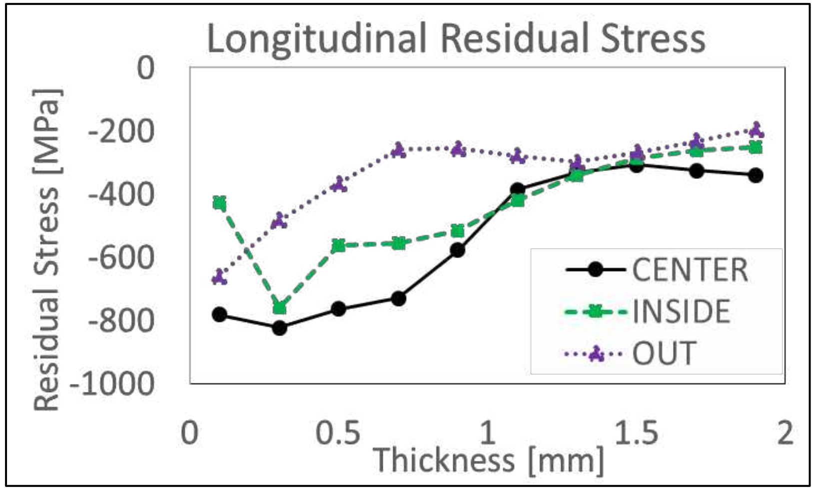
Elms analyzed in the thickness dir.

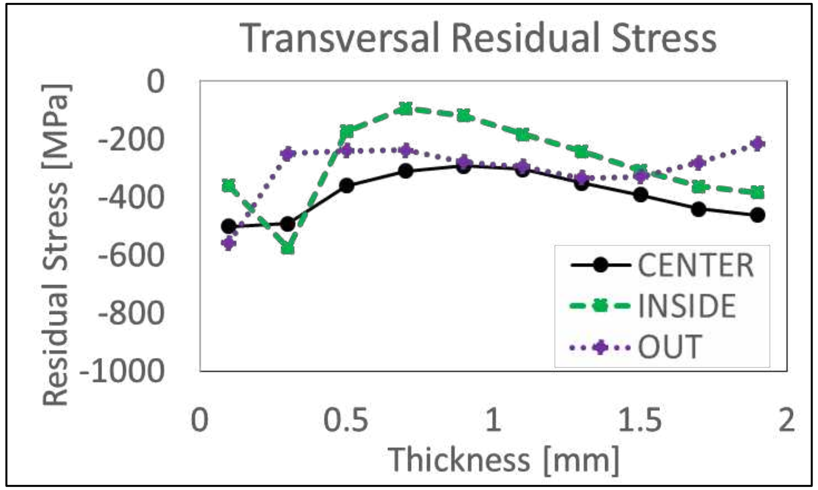


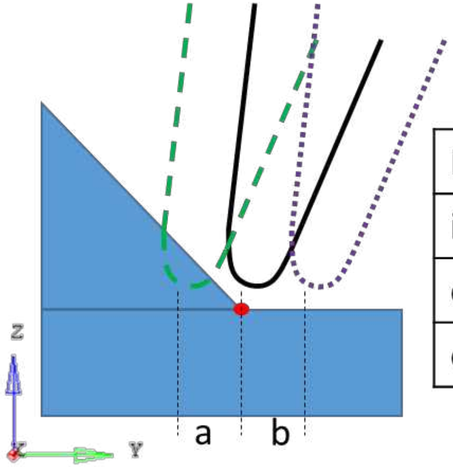
Weld Toe Profile due to Different Tool Angles (Syy)



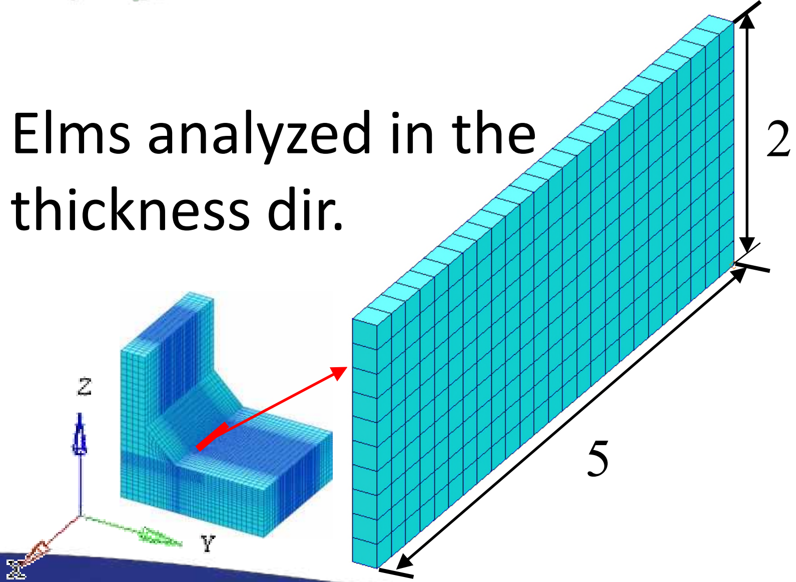
Peening Response due to Impact Position



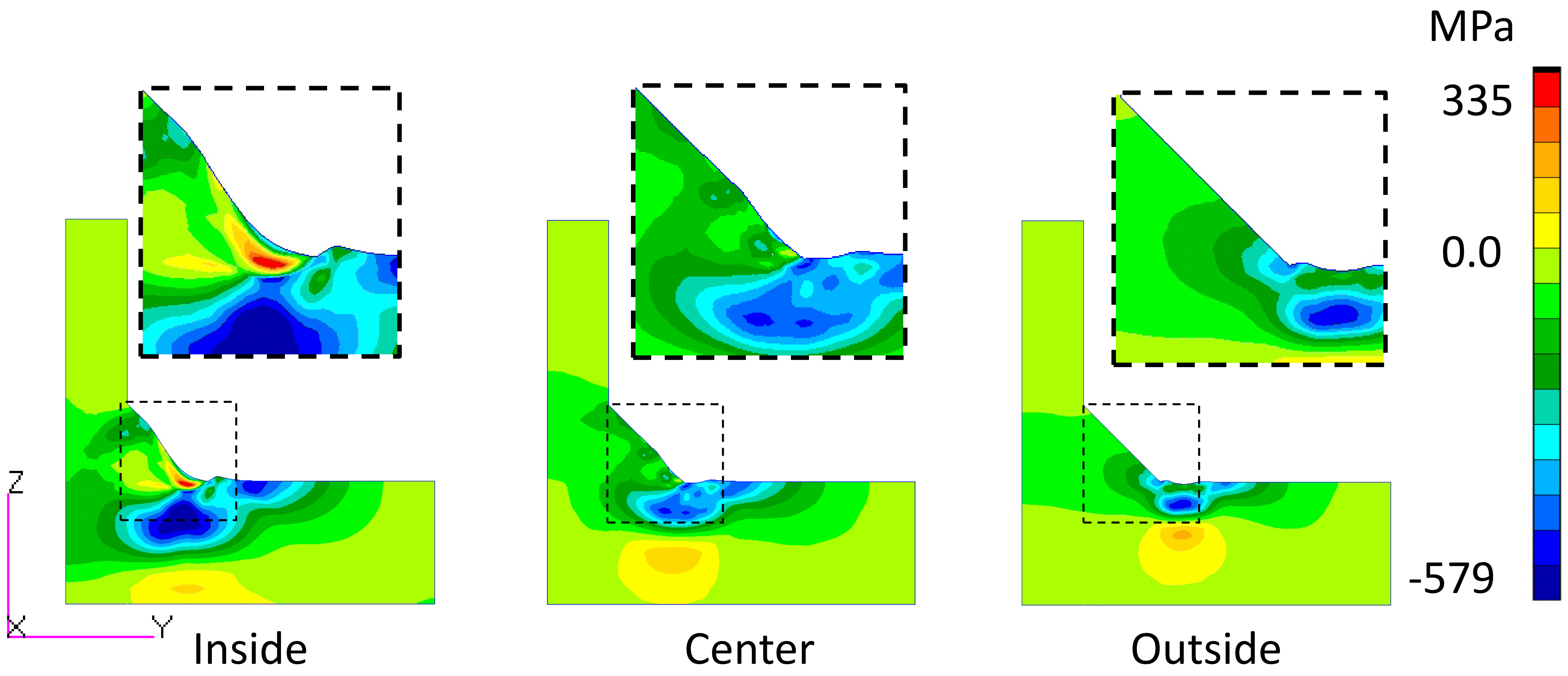




Position	Distance
inside	a= -1 mm
center	0
outside	b= 1 mm

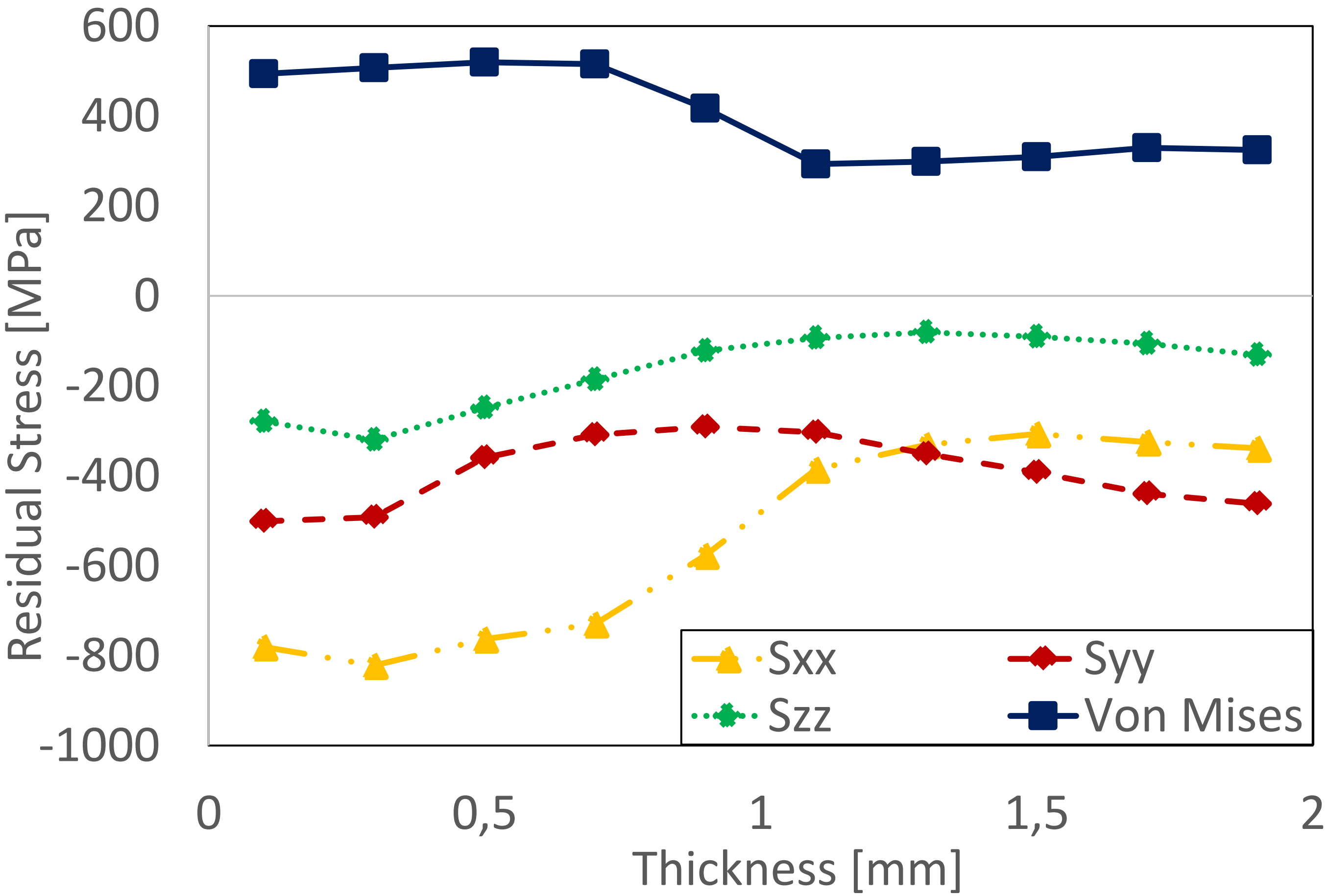


Weld Toe Profile due to Different Impact Position (Syy)



Peening Animation

- **Stresses are taken from center case.**



Conclusions

- *This study has shown that a practical analysis of compressive residual stresses induced by HFMI-treatment, accurately represent the behavior.*

- *The present study of different tool angles has shown that same behavior and similar residual stresses close the top surface are obtained. However, smooth changes of RS in the thickness direction are observed with an angle of 75^o regarding to the flange.*

- *The study of peening response due to impact position has shown significant sensitivity. It is found that inside case shows abrupt changes of RS close to the top surface. Outside case shows smaller compressive RS in the thickness direction, getting smooth changes when the impact position is over the weld toe.*

Further works

- Perform welding followed by HFMI and cyclic loading analysis to investigate the stability of compressive residual stresses induced by HFMI.
- Analyze the residual stresses induced by HFMI with different hardening materials.

Acknowledgement

Authors would like to thank the contribution of the members of this ISSC 2018 committee Prof. Lennart Josefson (Chalmers University of Technology), Prof. Heikki Remes (Aalto University), Prof. Myung Hyung Kim, Prof. Naoki Osawa (Osaka University), and Prof. Sherif Rashed (Osaka University).

Muchas gracias por su atención!

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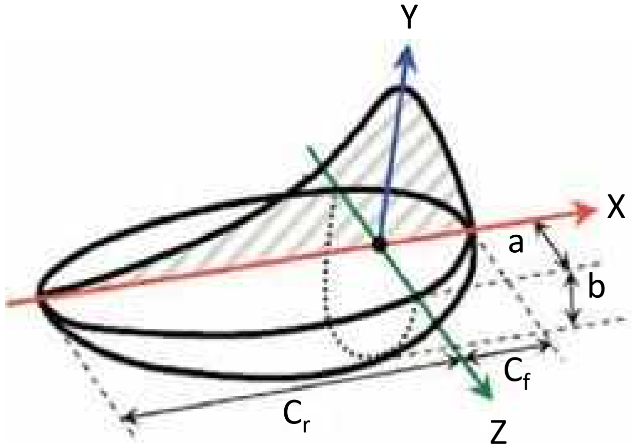
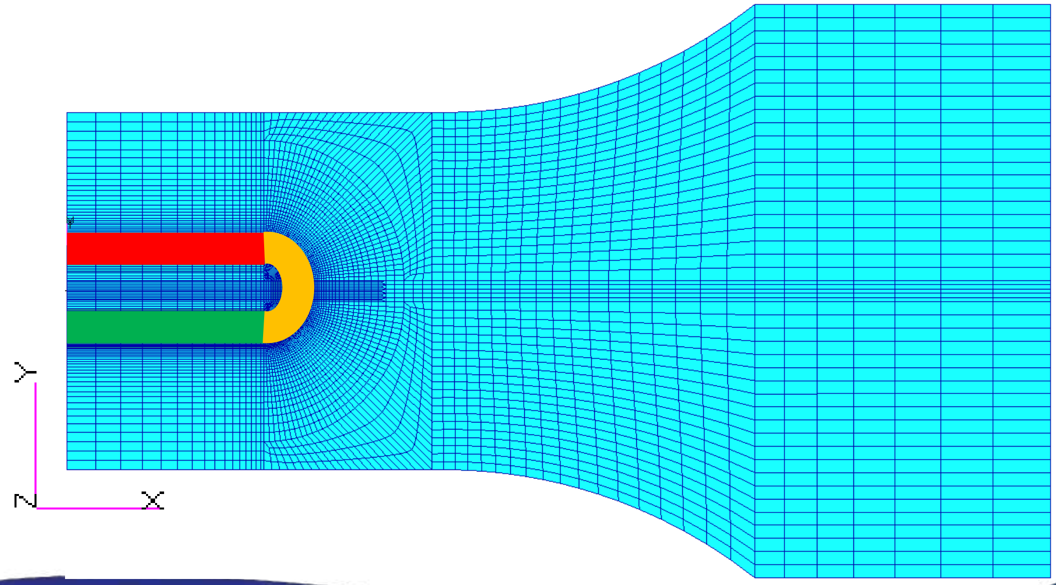
Welding Conditions

Pass	Joint Type	Ampere	Voltage	Travel Speed (mm/s)	Efficiency
1	Fillet Seam_1	260	21	8.5	0.85
2	Rounded Seam	260	21	8.5	0.85
3	Fillet Seam_2	260	21	10.2	0.85

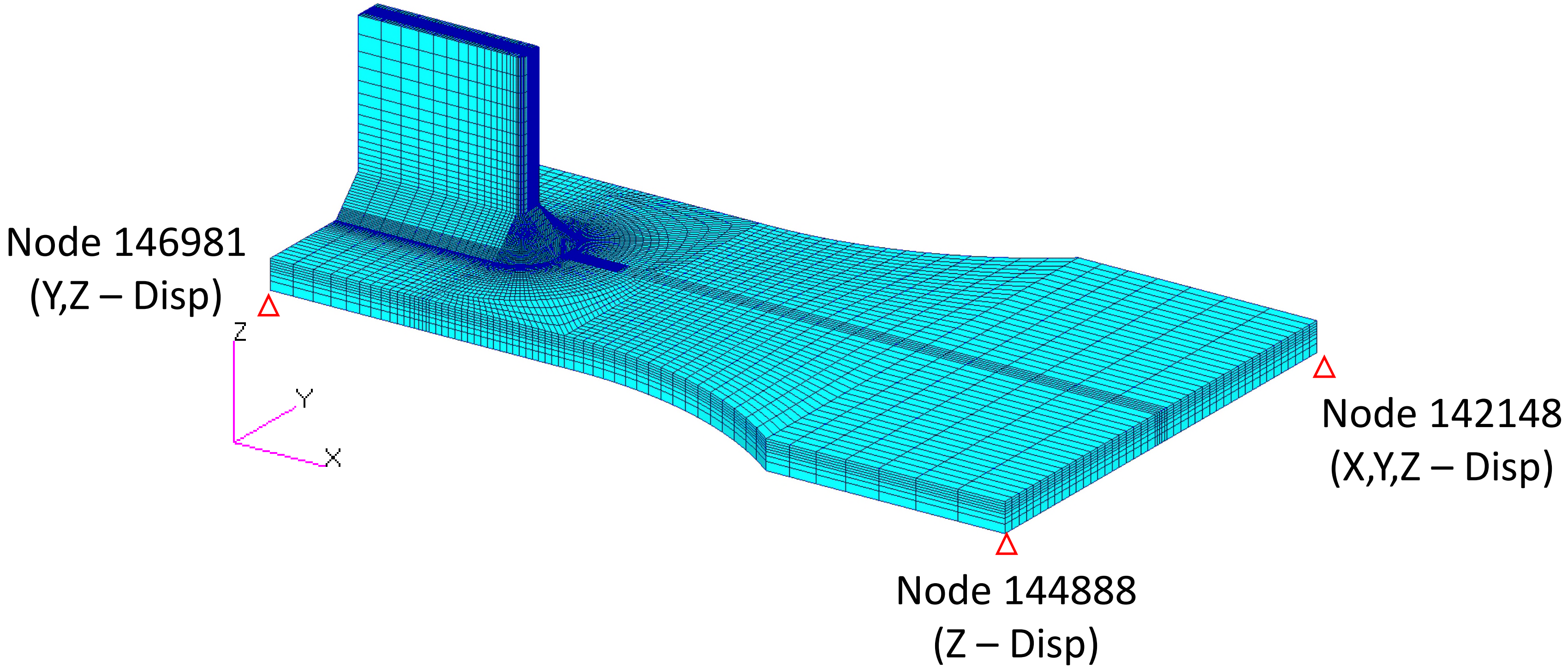


Dimensions
a=6mm
b=5mm
Cf=4mm
Cr=5mm

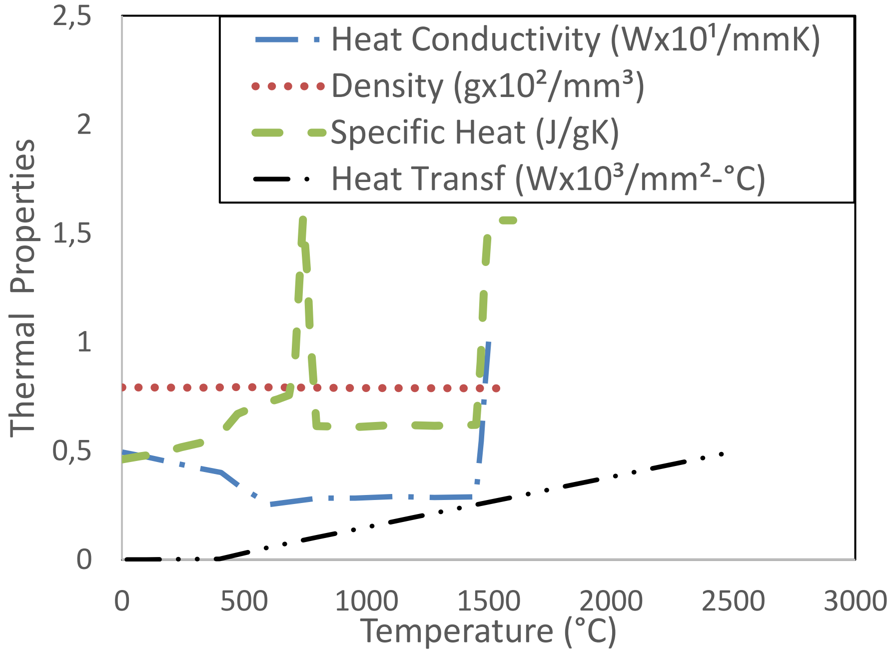
Goldak Heat Source Model



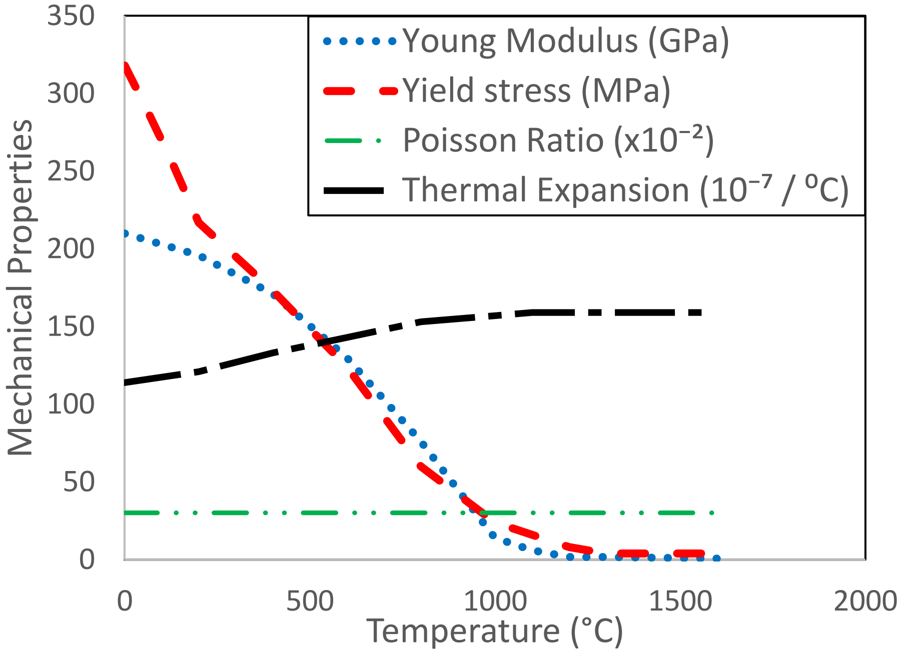
Boundary Conditions



Material Properties



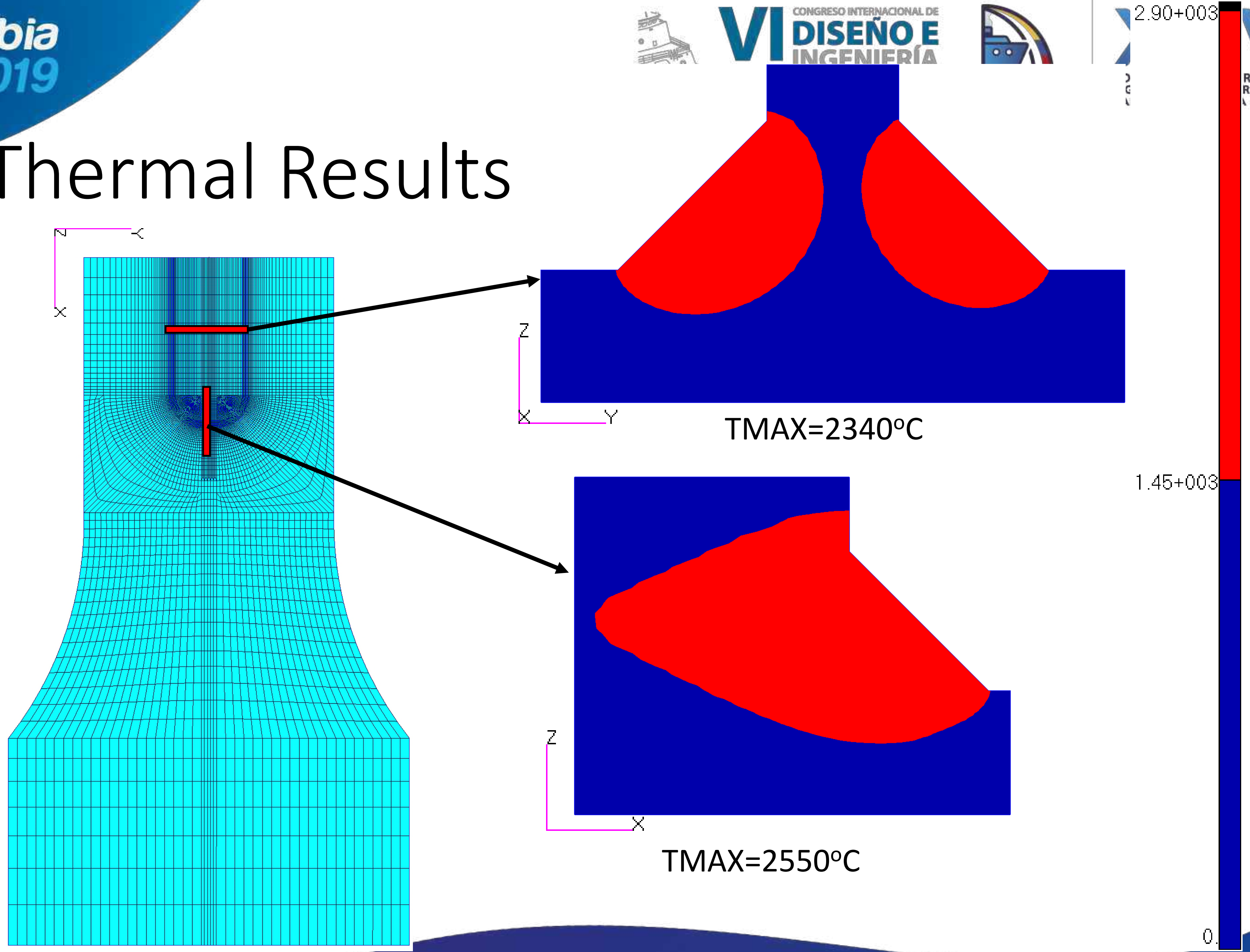
Thermal Properties



Mechanical Properties

*Provided by Prof. Kim (Pusan National Univ.)

Thermal Results

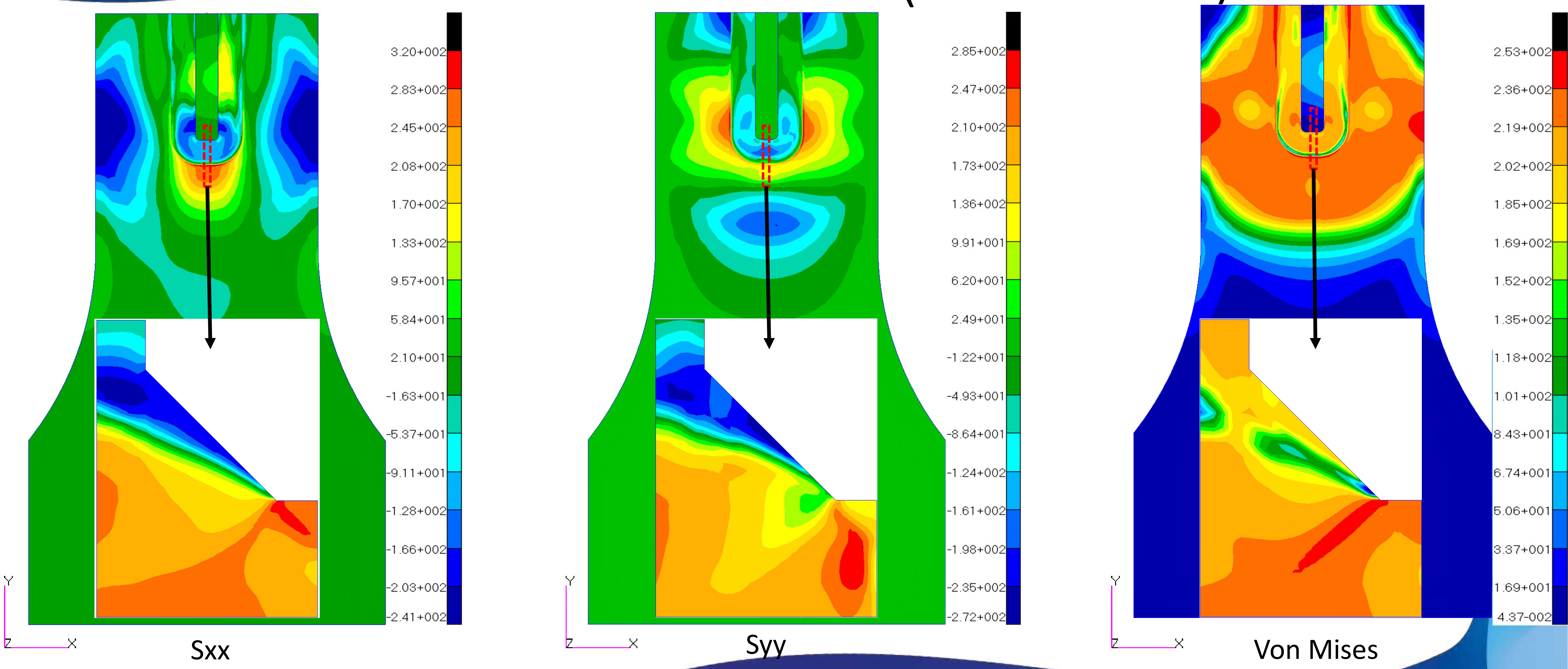


TMAX=2340ºC

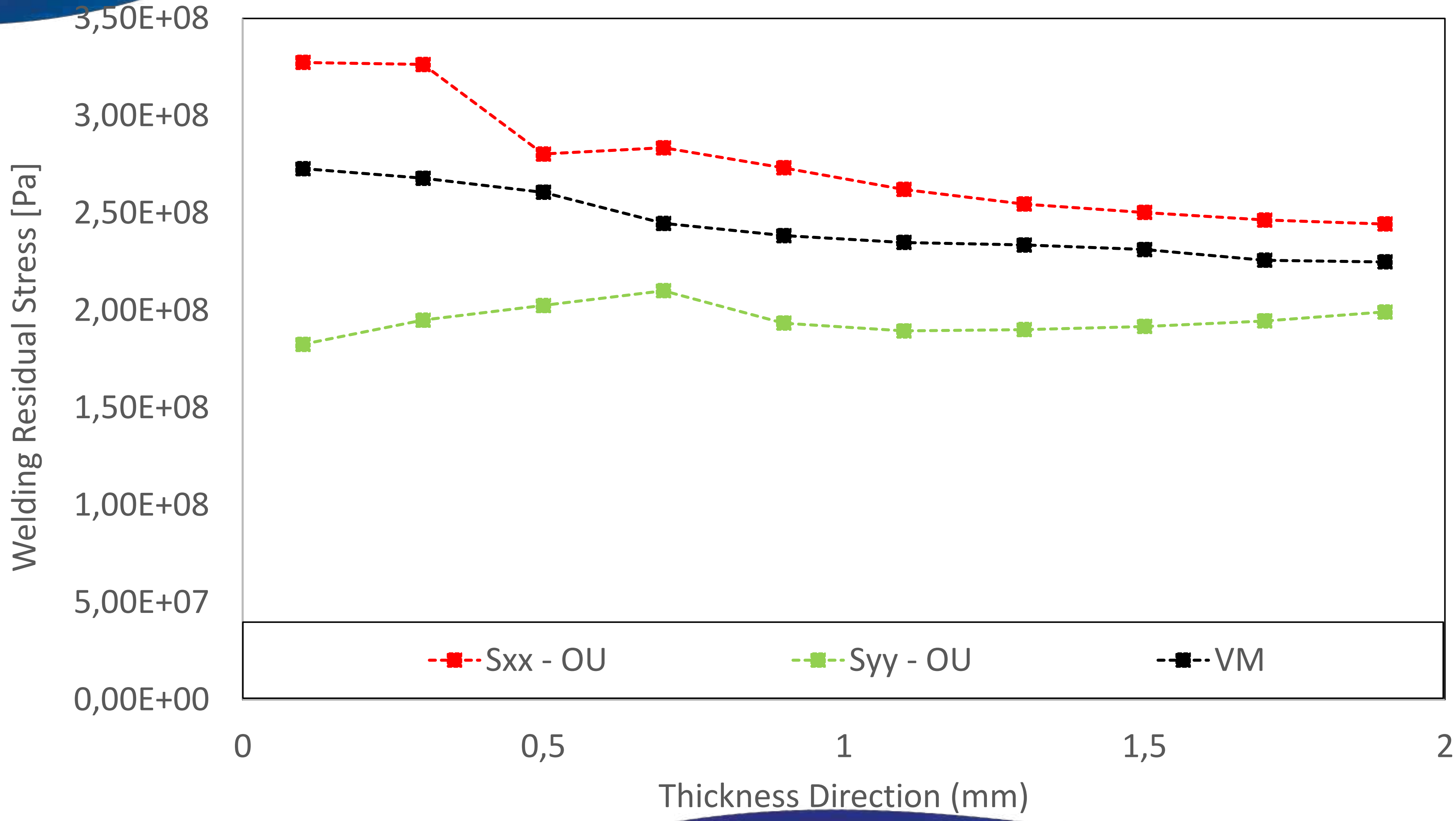
TMAX=2550ºC

Mechanical Results (as welded)

UNITS in MPa



Mechanical Results



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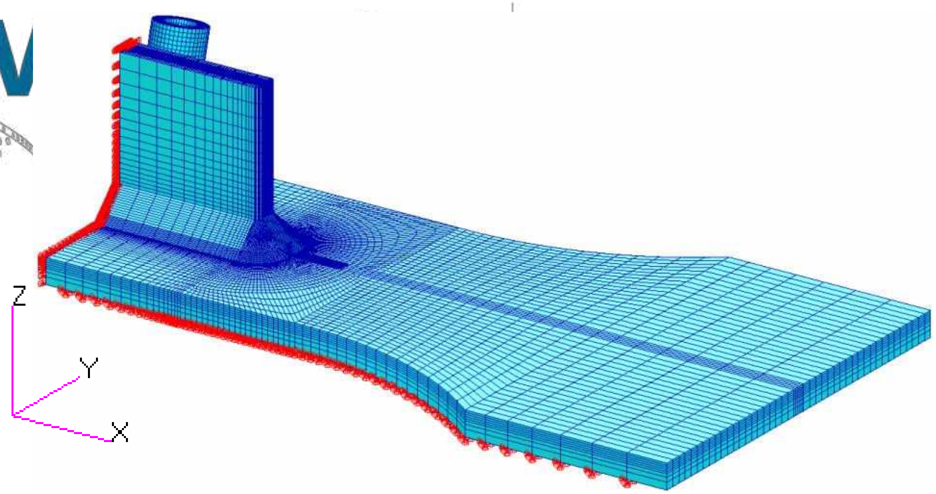
HFMI Analysis



Boundary Condition 1

Symmetric Face

- All nodes are fixed in X-Disp.
- Additionally, node 43671 is fixed in Y-Disp.

Nodes 146919 and 146981 are fixed in Z-Disp.

Bottom Surface

- All nodes are fixed in Z-Disp.

*Nodes on the bottom surface of the symmetric face are not fixed in Z-Disp. Only nodes 146919 and 146981 are fixed in Z-Disp.

Boundary Condition 2

Symmetric Face

- All nodes are fixed in X-Disp.
- Additionally, node no. 43671 in Y-Disp.

Nodes 146919 and 146981 are fixed in Z-Disp.

Bottom Surface

- All nodes in X,Y,Z-Disp.

*Nodes on the bottom surface of the symmetric face are not fixed in Y,Z-Disp. Only nodes 146919 and 146981 are fixed in Z-Disp.

Hardening Material Model

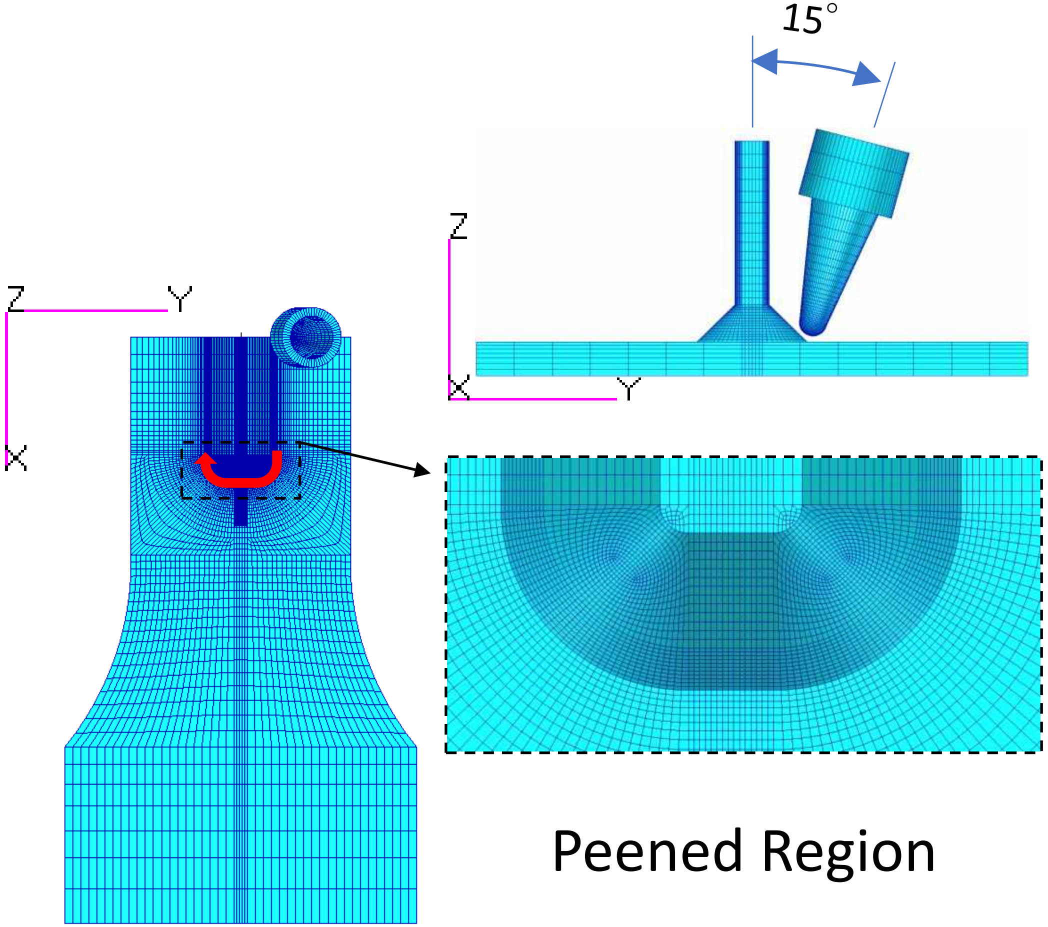
- Chaboche's kinematic Hardening Model is implemented
- Strain rate is not considered
- Pure Kinematic hardening material is considered

E [GPa]	ν	σ_o [MPa]	C1 [MPa]	$\gamma 1$	C2 [MPa]	$\gamma 2$
210	0.3	435	8971.8	218.65	12654.88	106.98

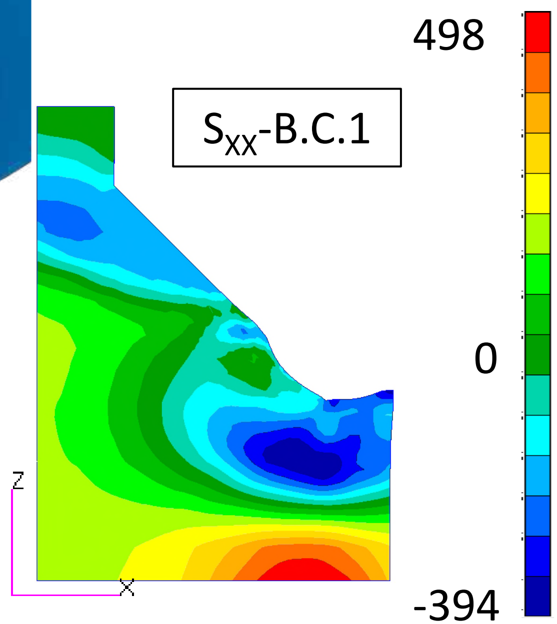
*Material Parameter in ABAQUS for S355J2H (kinematic hardening)

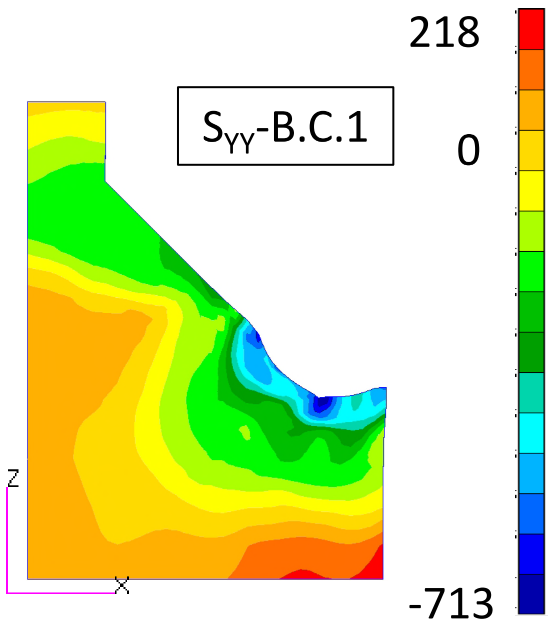
Peening Conditions

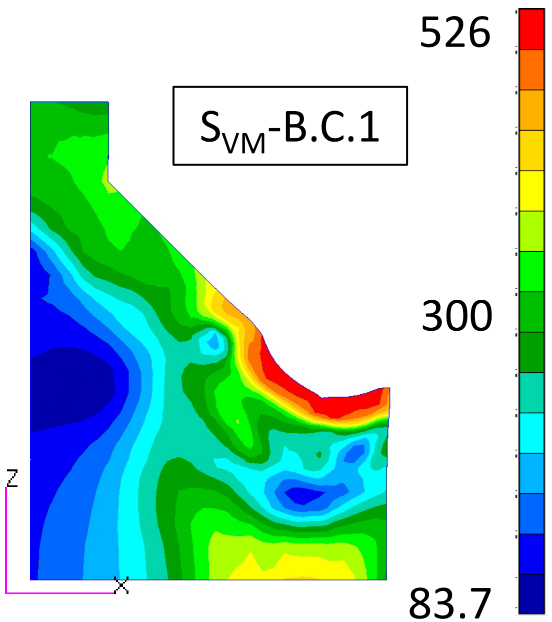
Peening Parameters			
Peening Radius	2mm	Pitch	0.4mm
Indentation	0.2mm	Frequency	100Hz
Length	23.7mm	Friction Coef.	0.3

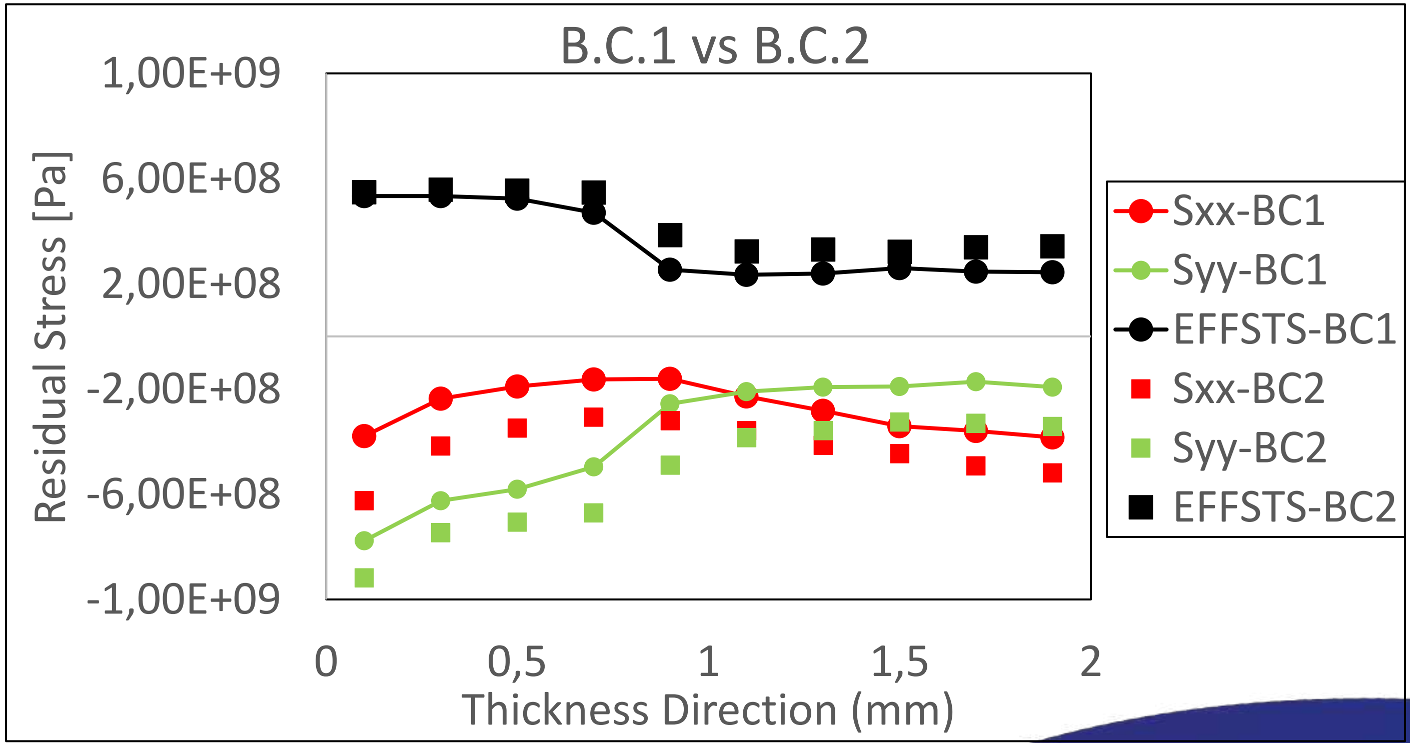


Results









Units in MPa