Influencing Welding Residual Stresses of HSS by Pneumatic Impact Treatment (PIT)

Authors:

Mizanur Rahman, Andreas Hütter, Norbert Enzinger

Institute of Material Science and Welding, TU Graz

Contact:

Email: m.rahman@tugraz.at

Contents

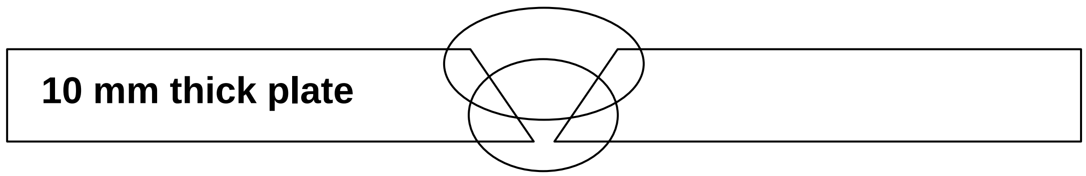
Introduction and motivation

- Focus on
  - The effects of post weld pneumatic impact treatment (PIT) on welding residual stresses
  - PIT
    - is the high frequency hammer peening method
    - pins are accelerated by air pressure
    - produces plastic deformation which results in beneficial compressive RS in the material

- To analyze these effects, 2D-FE simulations have been performed

Experimental procedure

- Welding
  - 2-layers MAG welding using twin electrodes



  - Materials

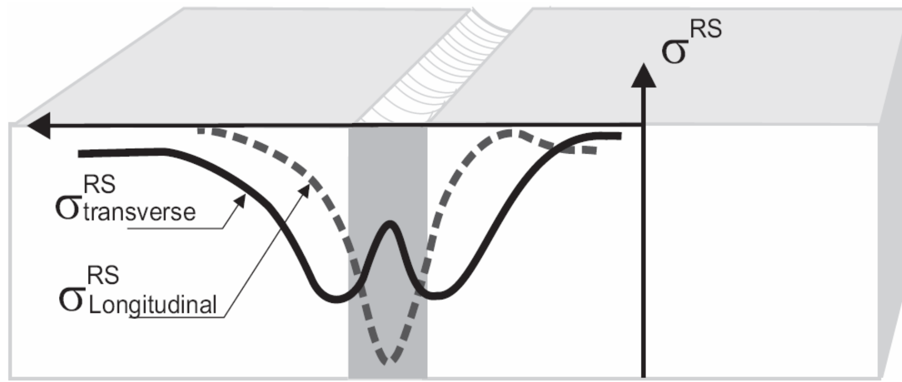
Strength	Base material, ALFORM 700M	Filler material X70IG
Yield strength	810 MPa	780 MPa
Tensile strength	1000 MPa	980 MPa

  - Welding parameters

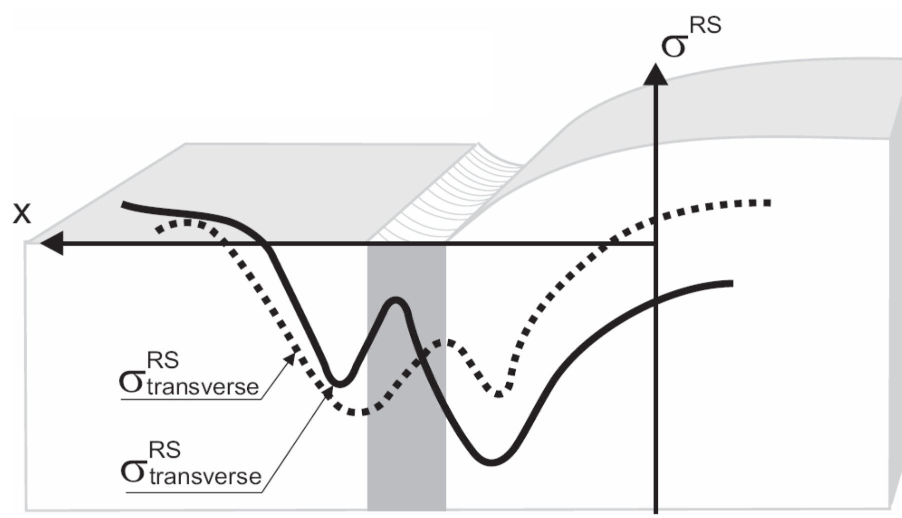
Layers	I_1 (Amp)	V_1(volt)	I_2 (Amp)	V_2(volt)	Velocity (mm/sec)	Line energy (kJ/cm)
Root	203.6	22.0	207.2	21.7	10	9.0
Top	209.8	25.7	205.9	23.6	9.5	10.8

Experimental procedure

- Pneumatic impact treatment (PIT)
  - on heat treated stress relief plate (initial state $S_{ij} \approx 0$ and $\varepsilon_{ij} \approx 0$)



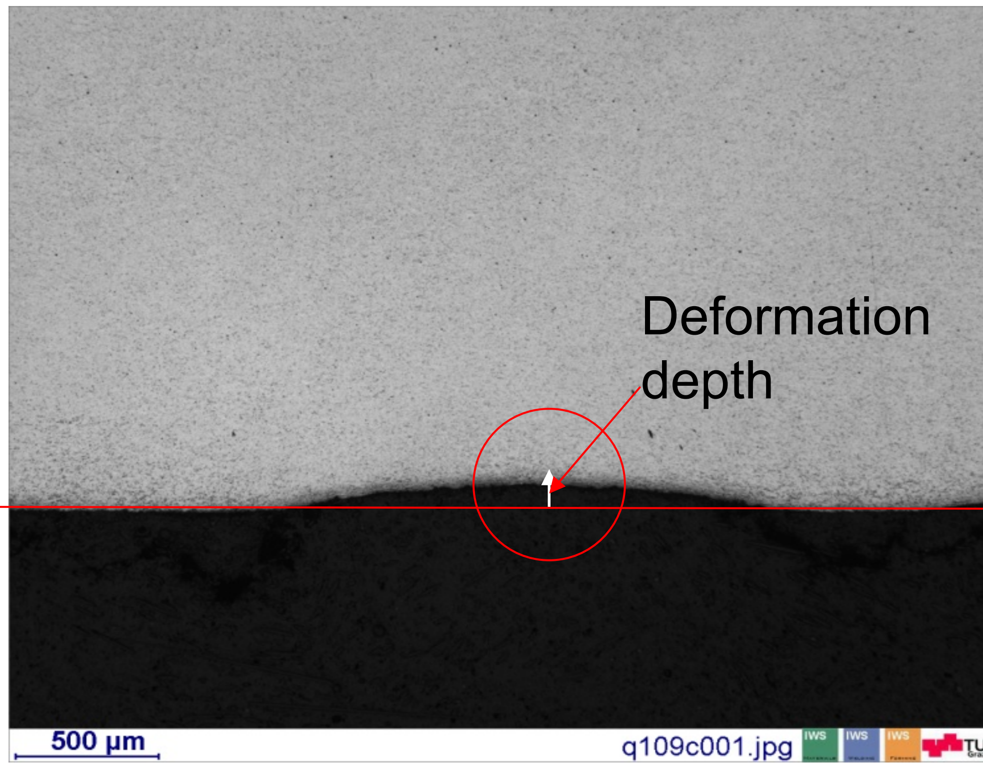
  - on welded part (initial state WRS)



[1]I. Weich, PhD-Thesis, TU Braunschweig, 2009

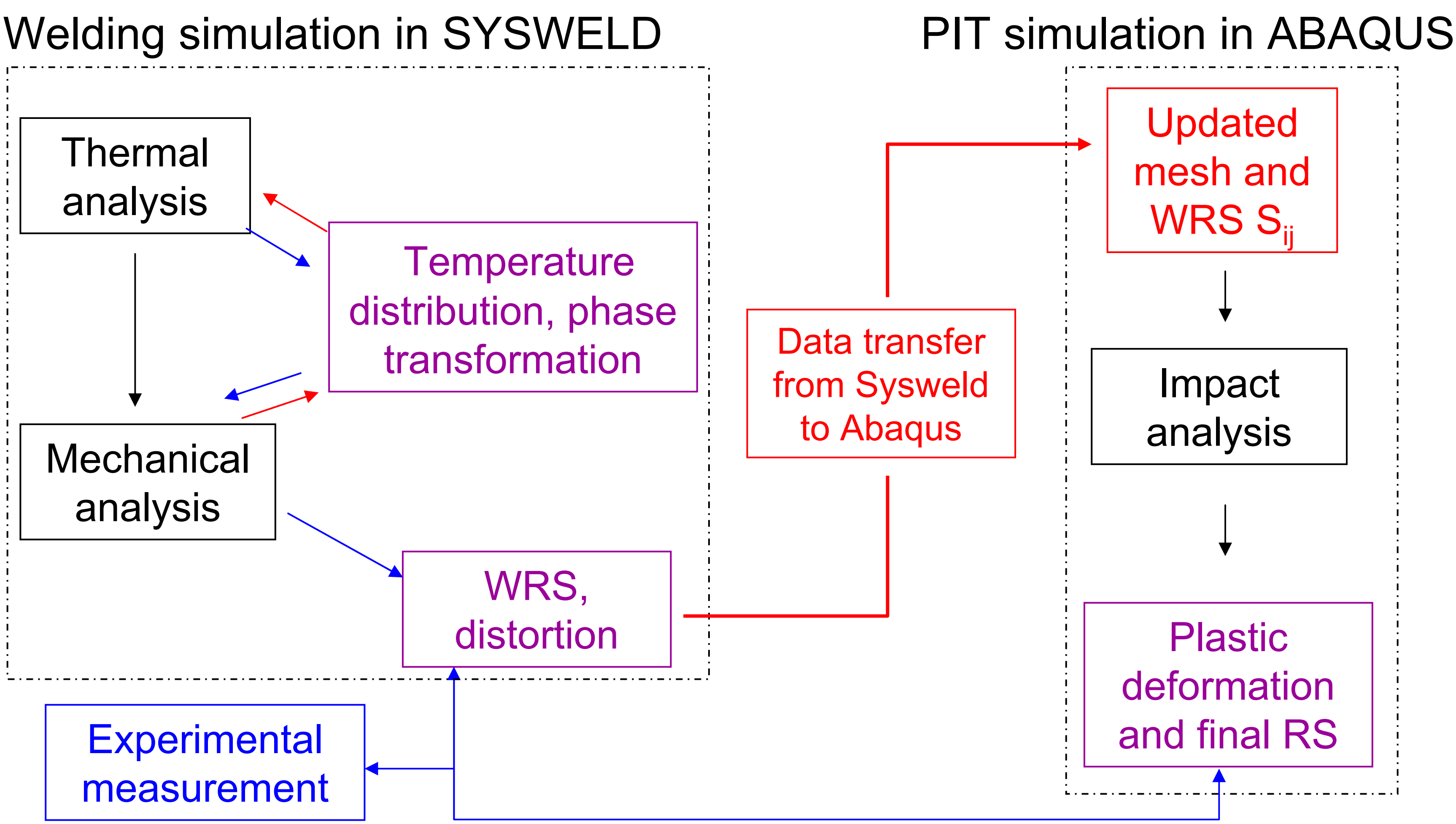
Experimental procedure

- Measurements
  - Welding and PIT residual stresses by hole drilling method
  - Deformation depth caused by PIT using metallography
    - 0.2 – 0.3 mm



Treated Surface

Modeling concept



Welding simulation in SYSWELD

- Thermal analysis
  - Phase transformation and CCT diagrams are incorporated

Leblond equation: $$\frac{dP}{dt} = \frac{P_{eq}(T) - P}{\tau(T)} . f\left(\frac{dT}{dt}\right)$$

for filler material, Aus, F, and B transformation

Köstinen-Marburger equation: $$f_m = [1 - \exp\{-b(M_s - T)\}].\gamma_{rest} \quad (T \le M_s)$$

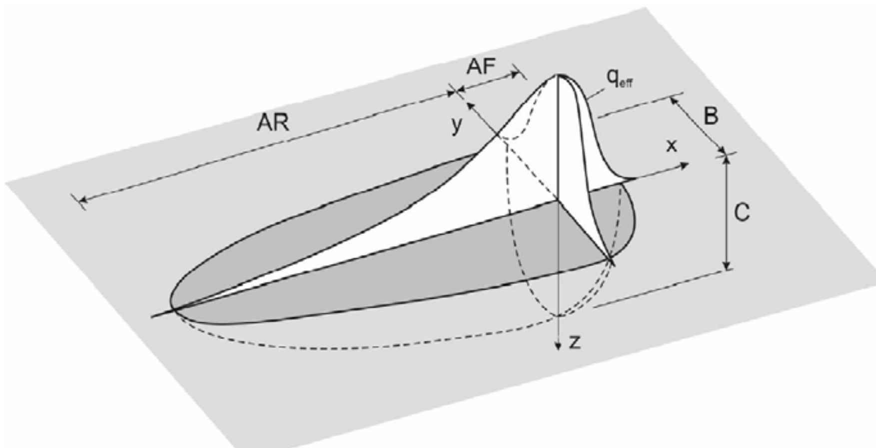
$$M_f = M_s - (215 \pm 15)°C$$

for martensite transformation

P_{eq}-phase equivalent, Tau-reaction criteria, f_m-fraction of martensite, M_s-martensite start and M_f-martensite finish temperature

Welding simulation in SYSWELD

- Thermal analysis
  - The double ellipsoid Goldak heat distribution was used in a 3D model to calculate



Front heat intensity:

$$q_f(x,y,z,t)=\frac{6\sqrt{3}f_f Q_{in}}{AF.B.C\pi\sqrt{\pi}}e^{-3(x-vt-x_0)^2/AF^2}e^{-3y^2/B^2}e^{-3z^2/C^2}$$

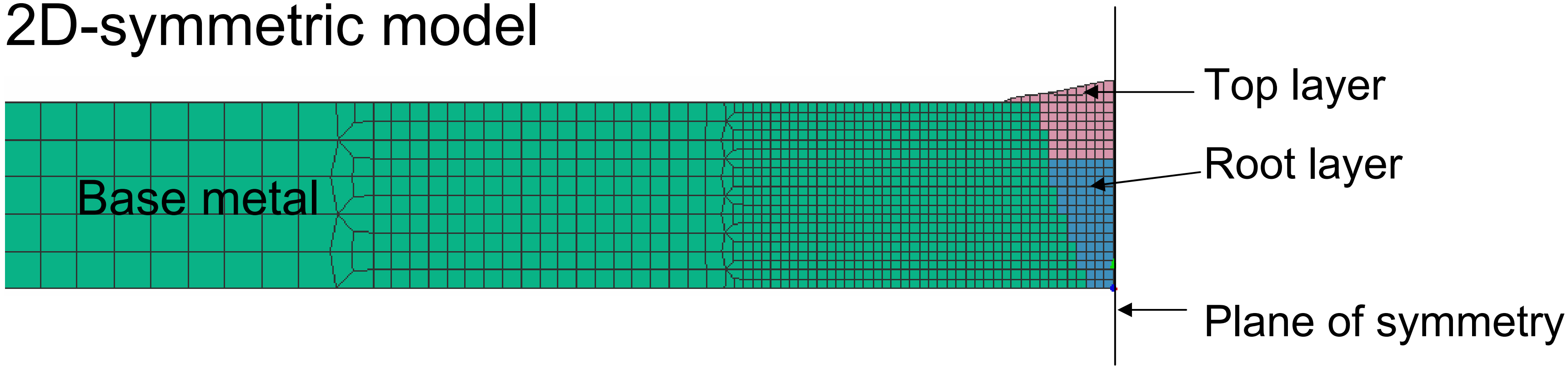
Rare heat intensity:

$$q_r(x,y,z,t)=\frac{6\sqrt{3}f_r Q_{in}}{AR.B.C\pi\sqrt{\pi}}e^{-3(x-vt-x_0)^2/AR^2}e^{-3y^2/B^2}e^{-3z^2/C^2}$$

  - Developed a Fortran subroutine

Welding simulation in SYSWELD

- 2D-symmetric model



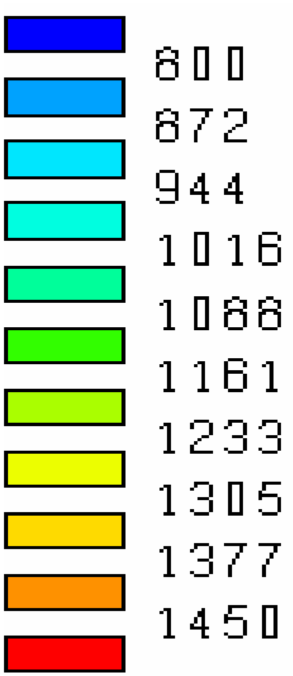
  – Thermal boundary conditions
    - Conduction: within the material

$$[\frac{\partial}{\partial x}(k\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(k\frac{\partial T}{\partial y})+\frac{\partial}{\partial z}(k\frac{\partial T}{\partial z})]+\dot{q}=\rho C\frac{dT}{dt}$$

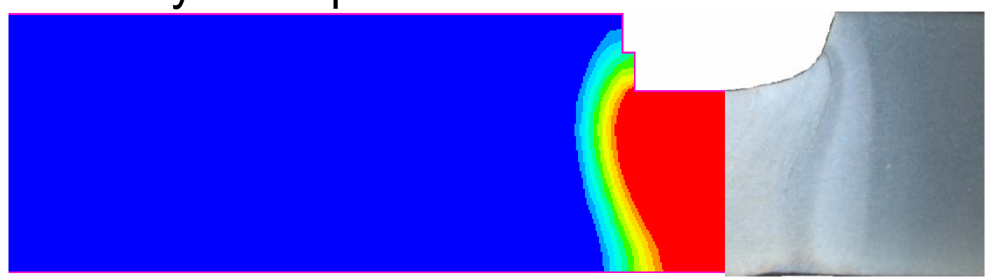
    - Radiation and convection heat loss from the material to the surrounding

$$Q=\{\frac{\varepsilon\sigma(T^4-T_0^4)}{T-T_0}+h_c\Delta T\}.A$$

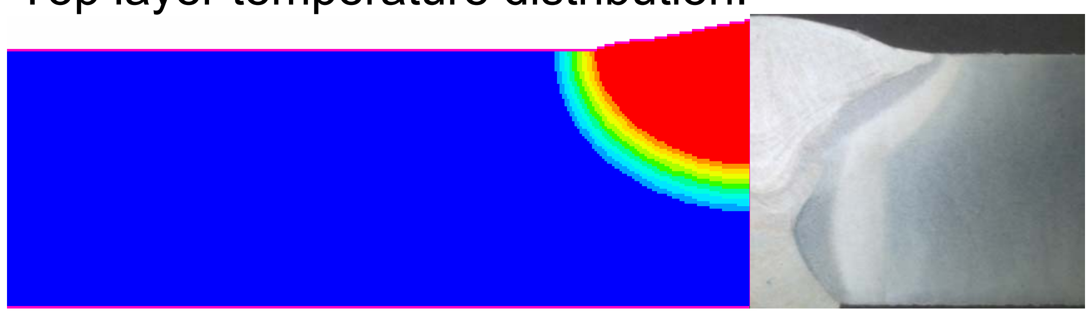
- Thermal results
  - Temperature distribution



Root layer temperature distribution:



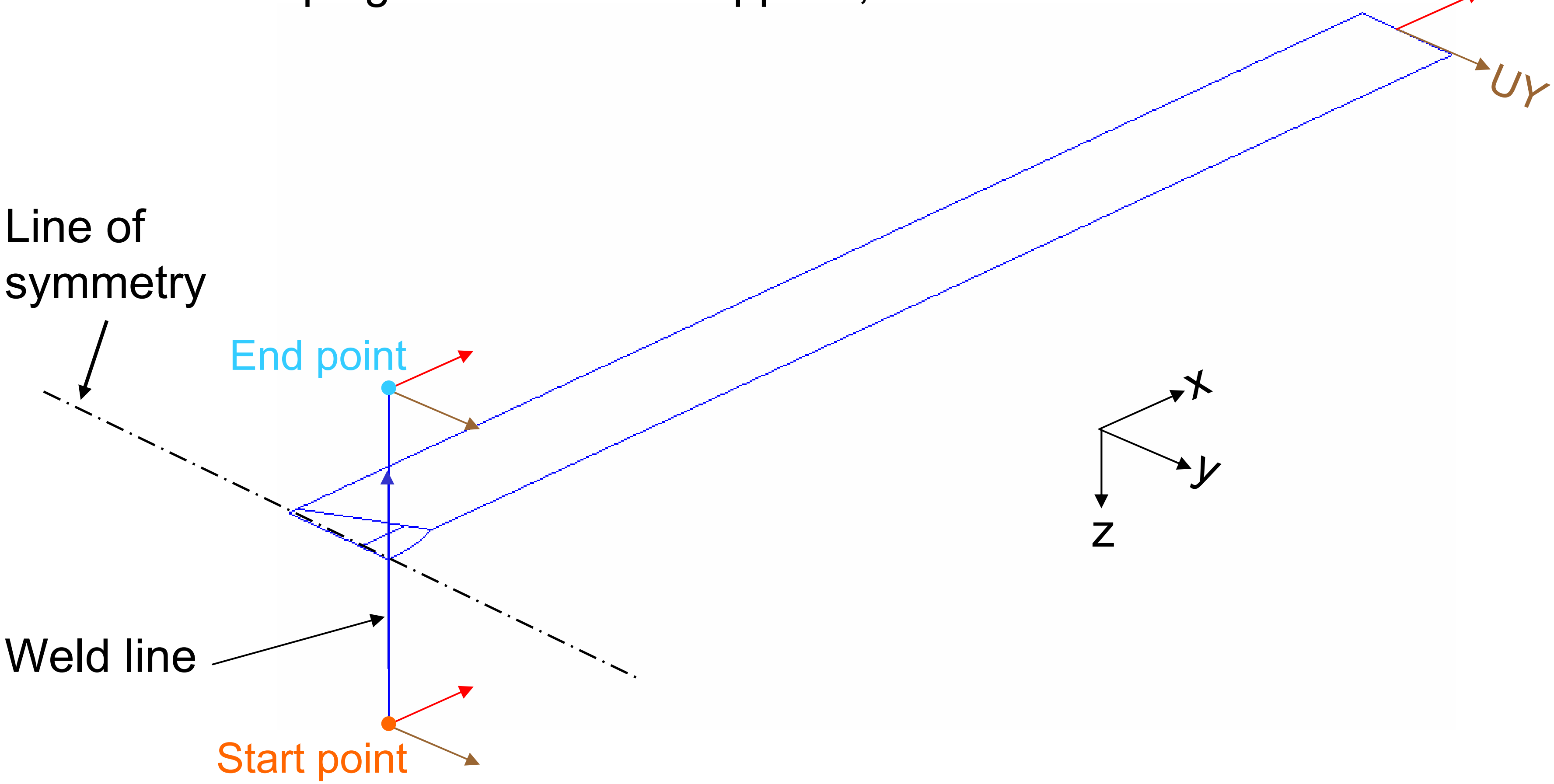
Top layer temperature distribution:



BACK

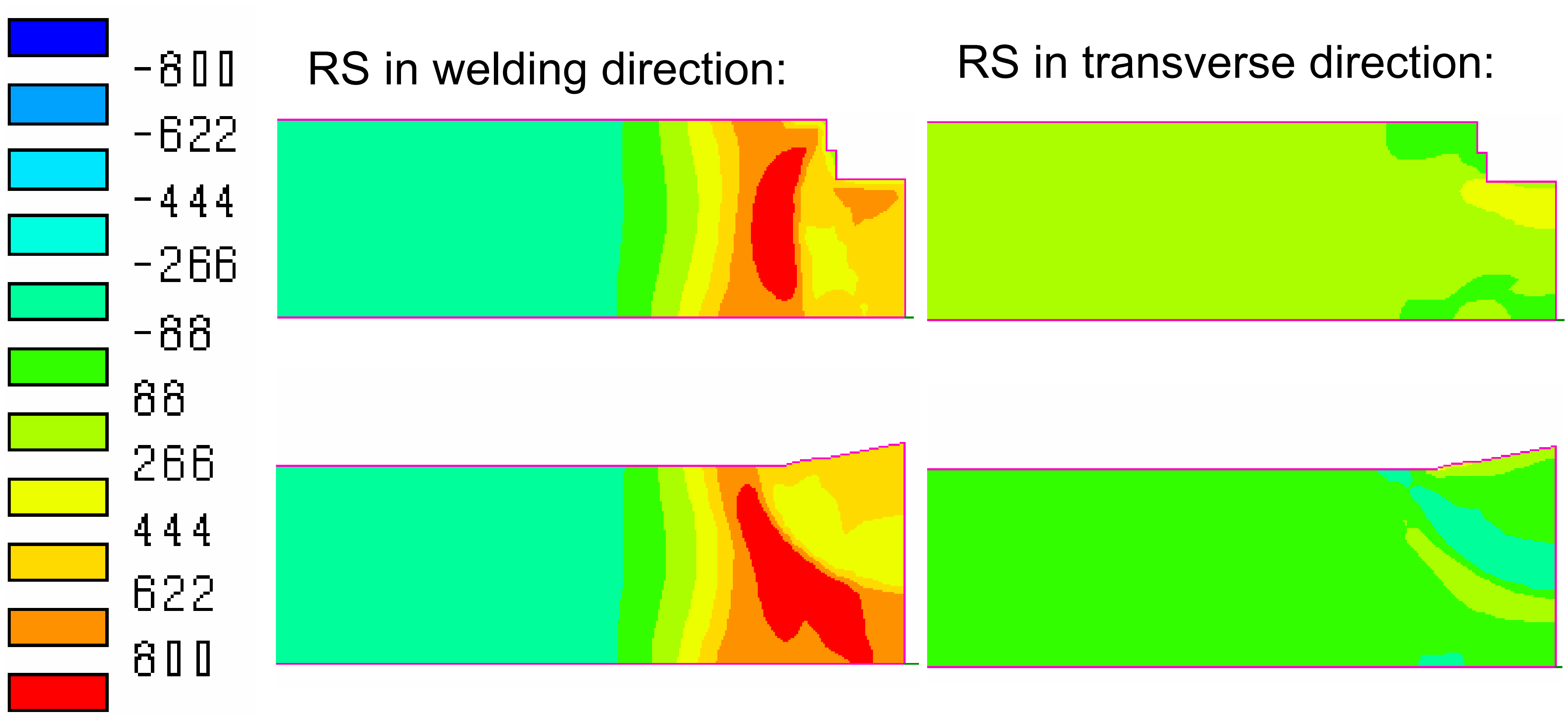
Welding simulation in SYSWELD

- Mechanical analysis
  - Fix clamping conditions are applied, UX=0 and UY=0



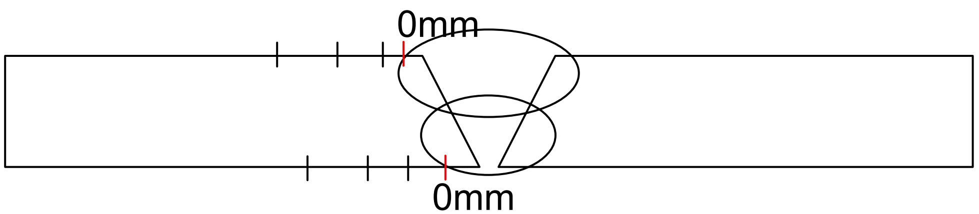
Welding simulation in SYSWELD

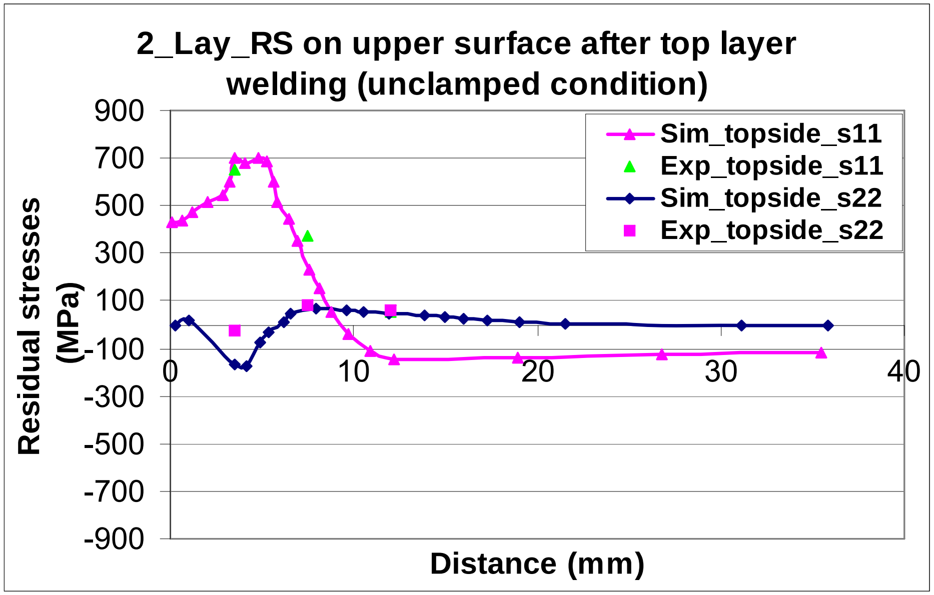
- Mechanical analysis results
  - Residual stress distributions

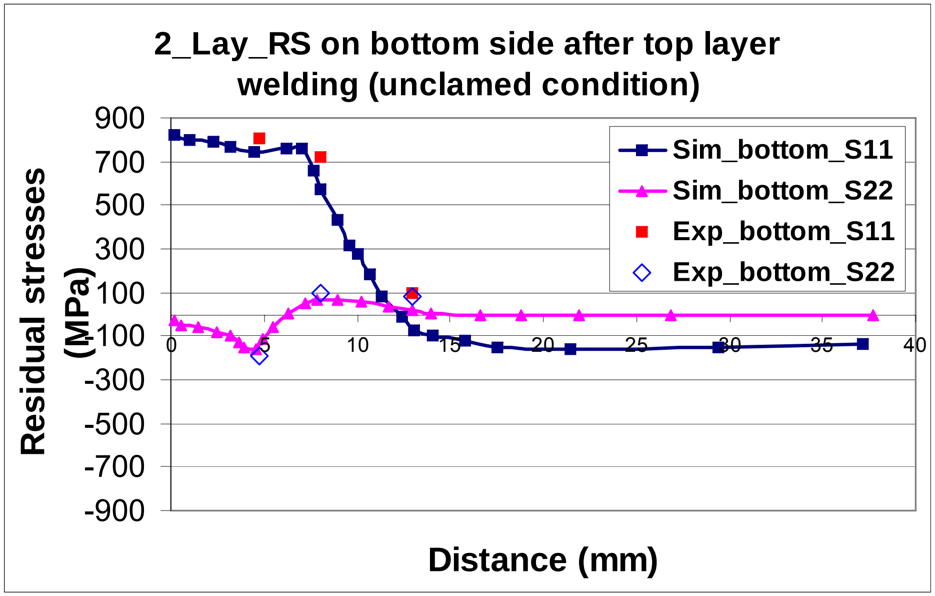


Welding simulation in SYSWELD

- Mechanical analysis results
  - Comparison between simulation and experimental results



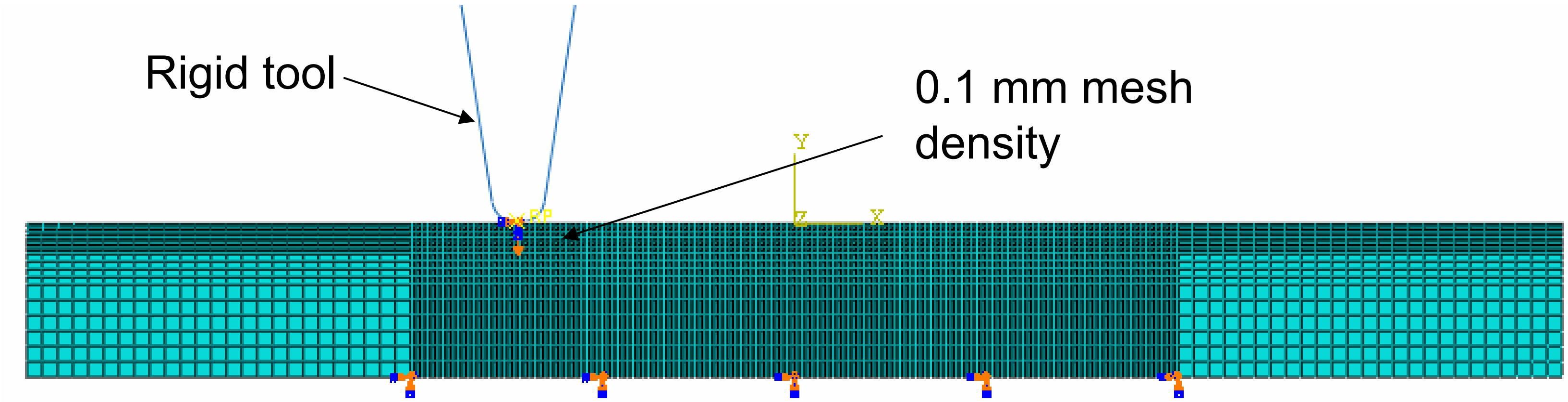




BACK

PIT simulation in ABAQUS

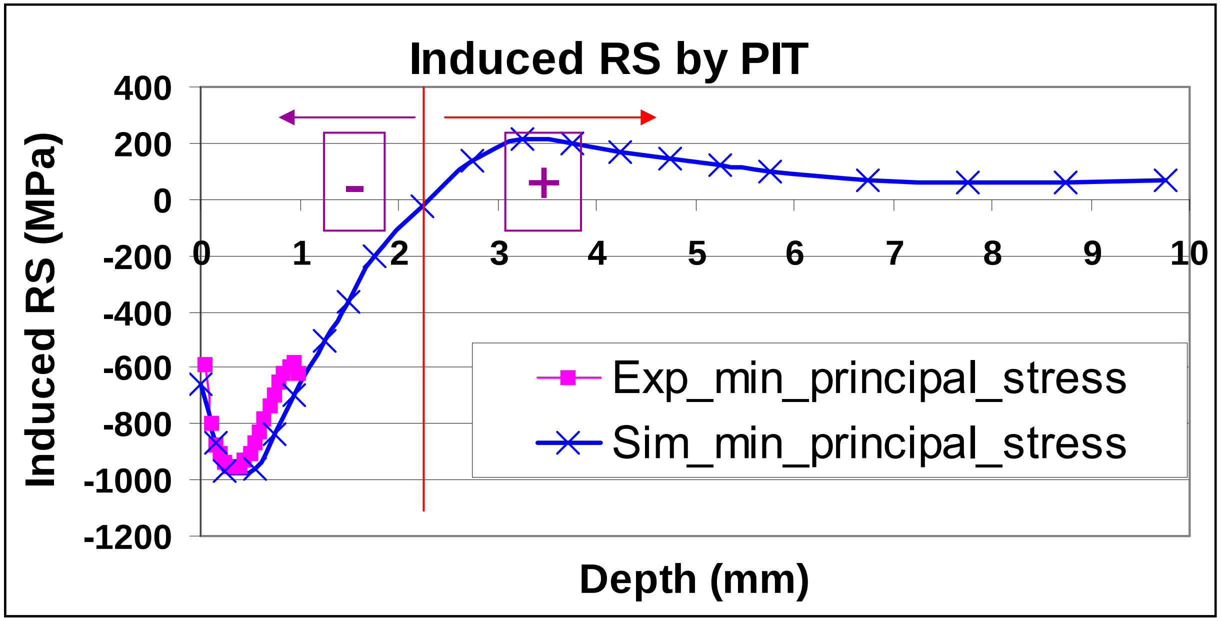
- PIT simulation
  - Without considering WRS (initial state, $S_{ij}=0$ and $\varepsilon_{ij}=0$)
    - 2D elasto-plastic model is used

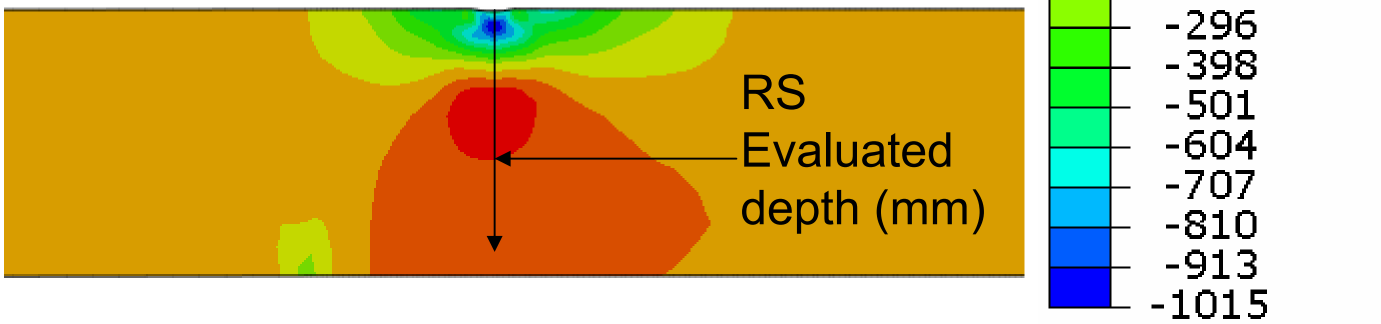


    - A single impact of 0.2mm impact depth is modeled using 3mm pin diameter
    - Simulation parameters are optimized for further PIT simulation on welded part

PIT simulation in ABAQUS

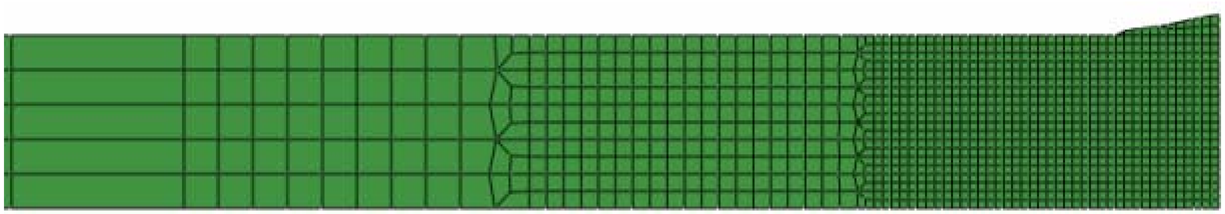
- PIT simulation results (without WRS)
  - Stress distribution induced by PIT





PIT simulation in ABAQUS

- PIT simulation on welded part
  - The mesh is transferred from SYSWELD to ABAQUS

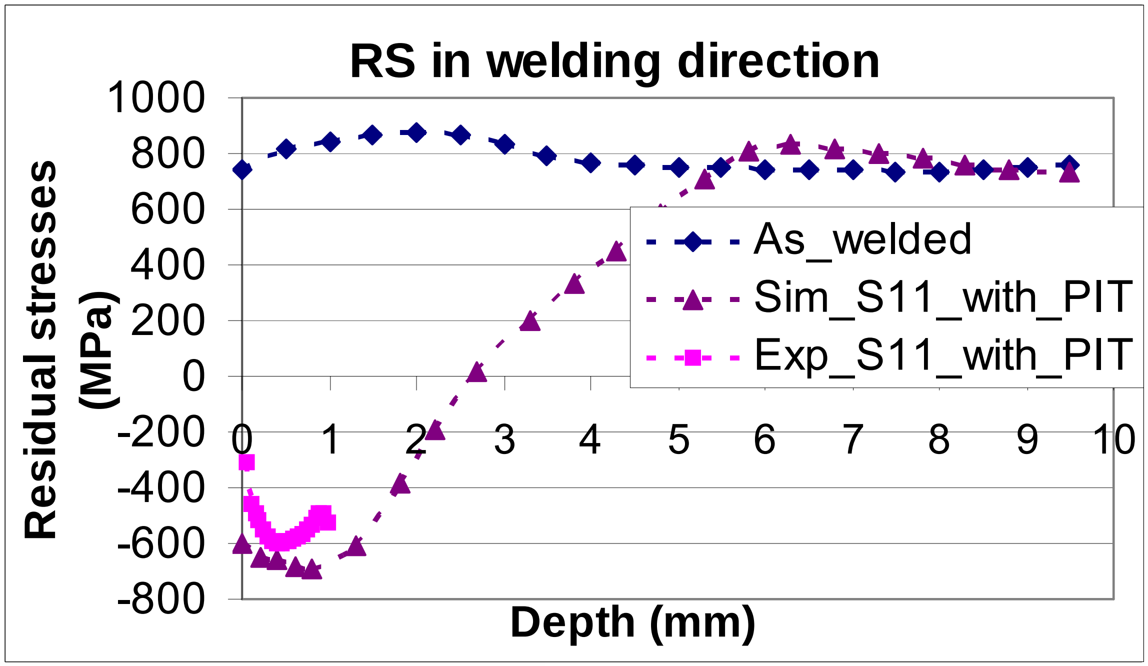


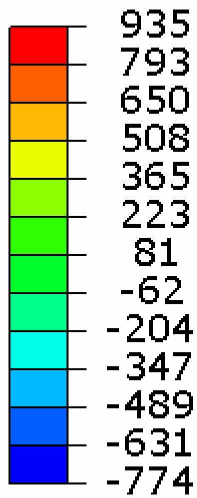
  - Welding residual stress components are included as initial condition and performed a static equilibrium calculation
  - And the PIT simulation is performed afterwards using optimized PIT parameters

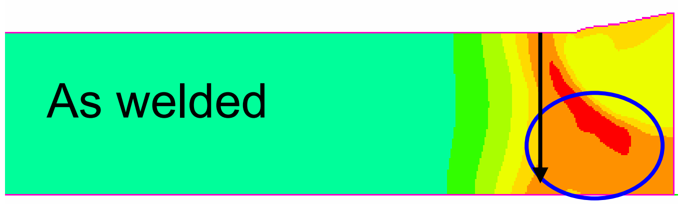
  LIMITATION: Not updated material properties after welding are used in the PIT simulation

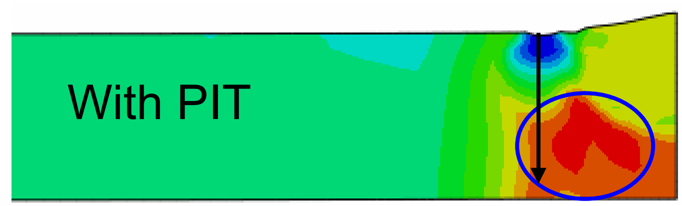
PIT simulation in ABAQUS

- PIT results on welded part
  - RS distribution in welding direction



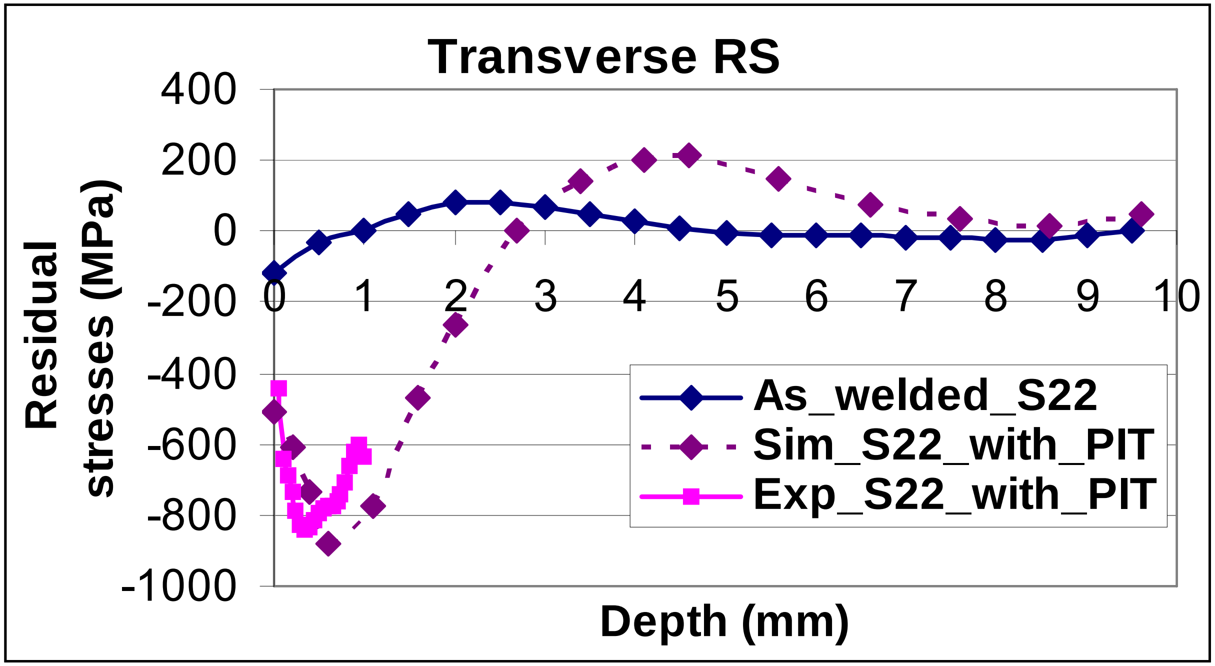


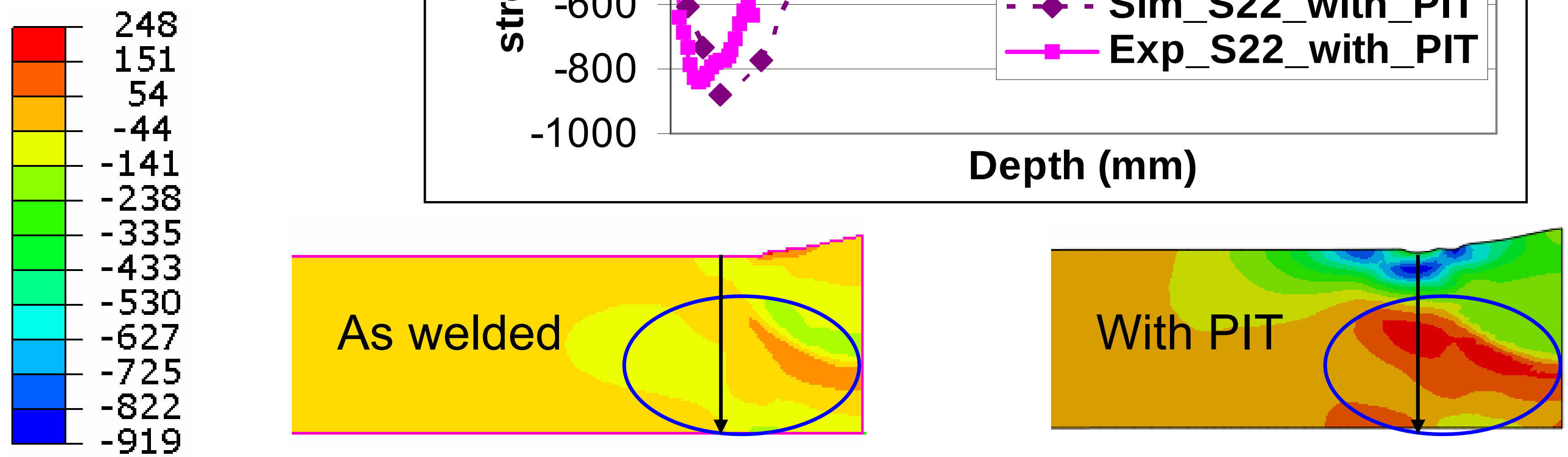




PIT simulation in ABAQUS

- PIT results on welded part
  - RS in transverse direction





Conclusion

- The induced RS by PIT has a great beneficial influence on WRS
- The WRS are redistributed and the compressive residual stresses are introduced in the material due to plastic deformation caused by PIT. The balancing tensile RS increase the overall tensile stresses at a certain limit in the material, but they may not be harmful for the component
- Superposition technique is not applicable where plastic deformation take place
- Welding and PIT simulation give a good agreement with the experimental results and a well prediction of RS distribution is possible using 2D FE-simulation

gefördert durch:

Acknowledgement

- PROJECT JOIN A11

THANKS FOR YOUR ATTENTION