

Methodologies for fatigue life determination in integral stiffened panels

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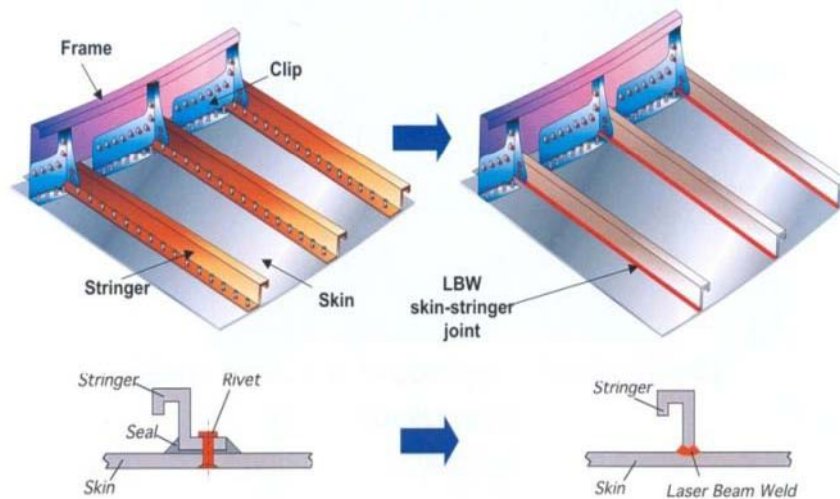
DaToN FP6 Project

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IDMEC – FEUP, Porto, Portugal

9th EASN Workshop on Mobility and Research
Munich, 27th–28th of November 2008

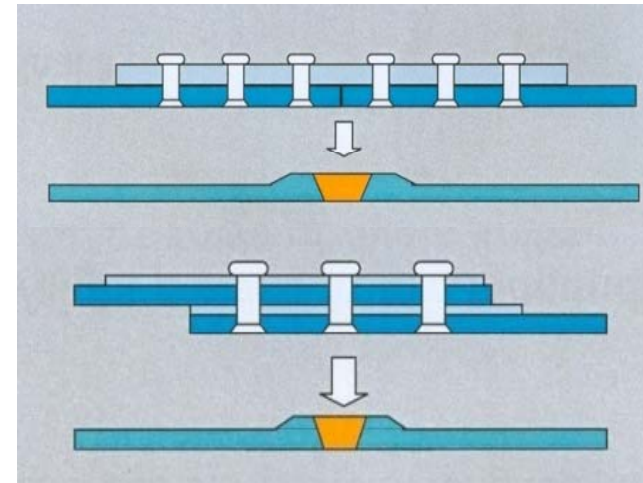
Differential vs. Integral structure

Differential and integral structure with LBW



M. Koçak, B. Petrovski, V. Uz; "Damage Tolerance Analysis of Laser Welded Short Distance Clip Welds using 4-Stringer Flat Panels"; European Workshop on Short Distance Welding Concepts for Airframes WEL-AIR, 13-15 June 2007, GKSS Research Center, Geesthacht (Hamburg) - Germany.

Replacement of longitudinal splice with a FS welded joint

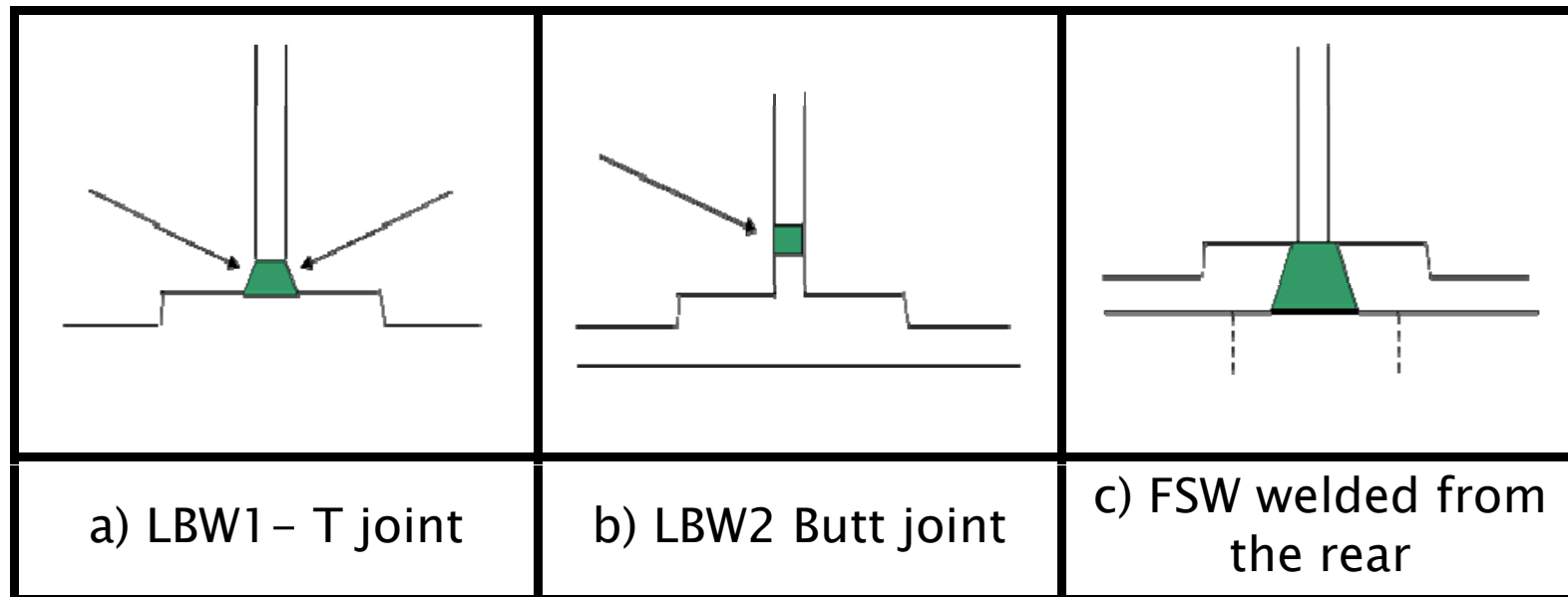


M. Pacchione, S. Werner, N. Ohrloff; Design Principles for Damage Tolerant Butt Welded Longitudinal Joints for Application in Pressurized Fuselages"; European Workshop on Short Distance Welding Concepts for Airframes WEL-AIR, 13-15 June 2007, GKSS Research Center, Geesthacht (Hamburg) - Germany.

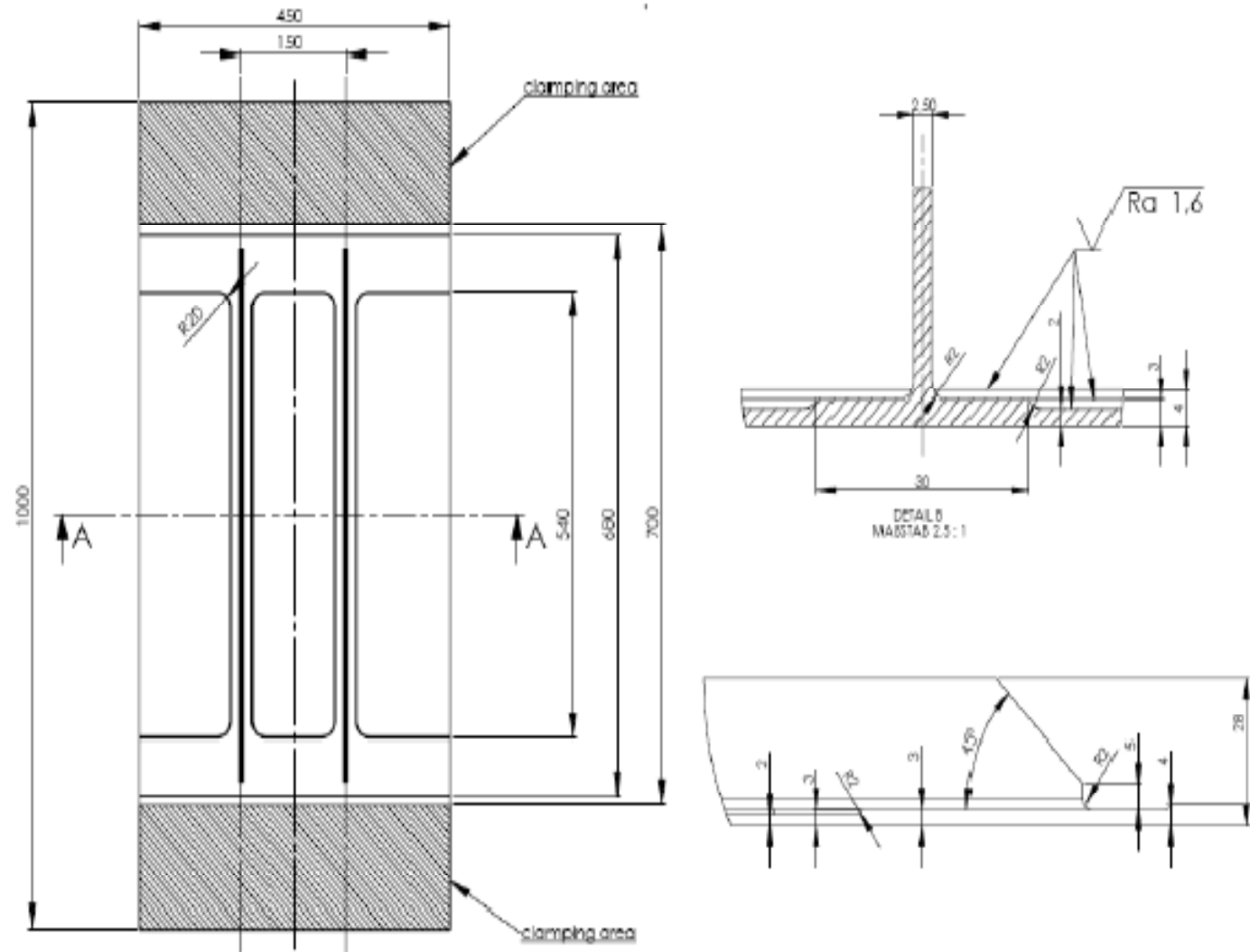
This is the most significant transformation in aircraft fuselage without large design modifications; however, they have different fatigue behaviours.

Manufacturing Process

- High Speed Machining (HSM)
- Laser Beam Welding (LBW)
- Friction Stir Welding (FSW)

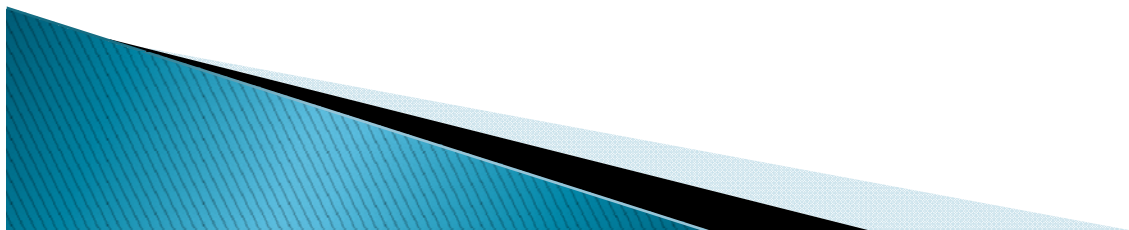


DATON specimen geometry

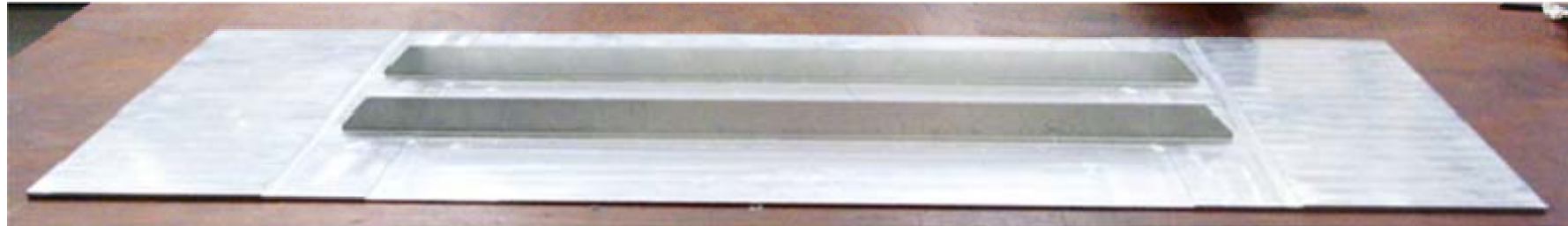


Configurations

Manufacturing Process	Material/Heat treatment		
HSM	AA2024-T3	AA6056-T6	
LBW-1	AA2024-T3	AA6056-T6 as welded	AA6056-T4 PWHT -T6
LBW-2	AA2024-T3	AA6056-T6 as welded	AA6056-T4 PWHT -T6
FSW	AA2024-T3	AA6056-T6 as welded	AA6056-T4 PWHT -T6



Distortion with these manufacturing processes



a) HSM panel (almost flat)



b) LBW panel

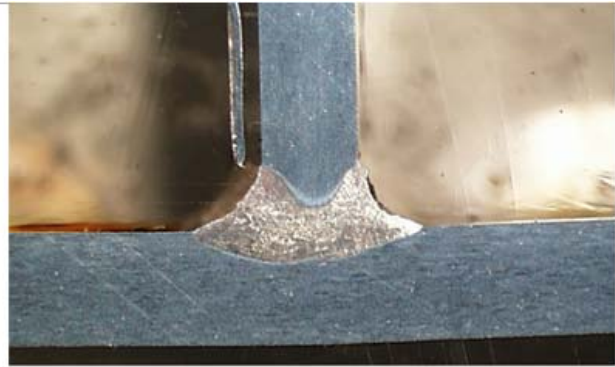


c) FSW panel

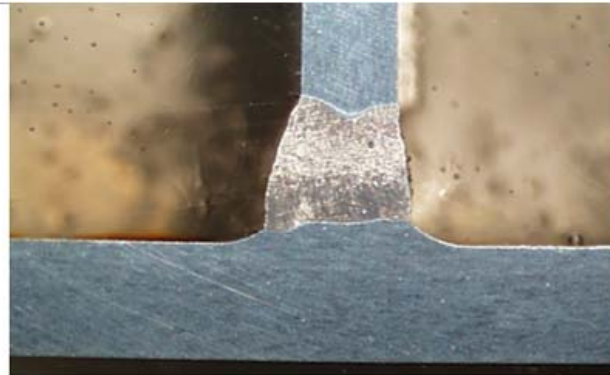
Experimental setup to measure the crack growth



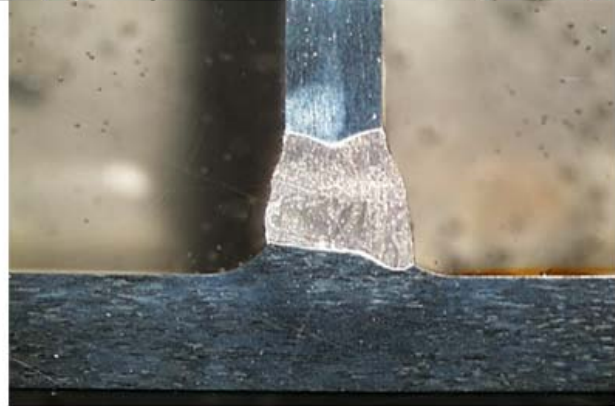
DATON Stiffened panels tested



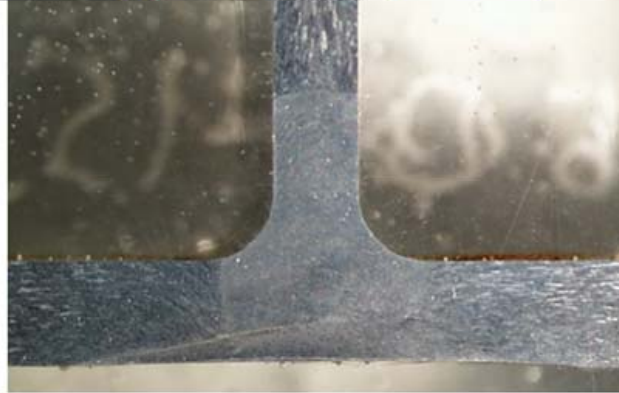
a) specimen LBW03 (LBW1 configuration)



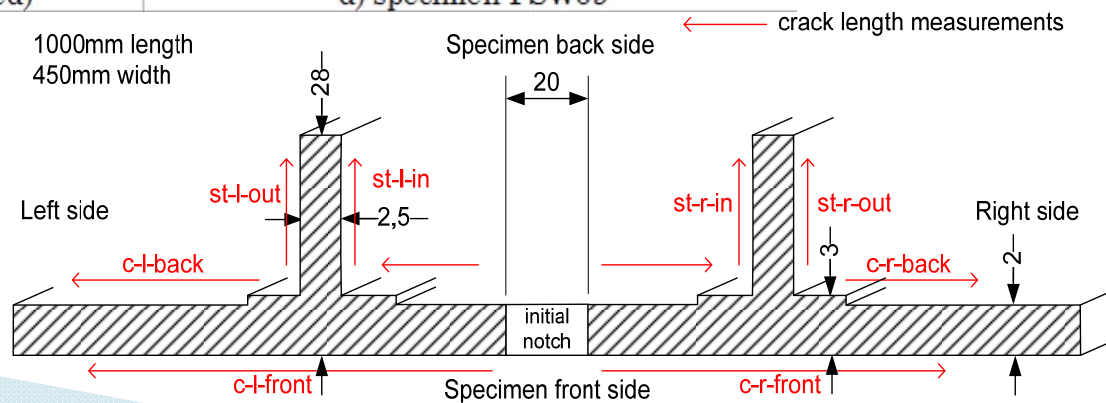
b) specimen LBW05 (PWHT-T6)



c) specimen LBW07 (as-welded)

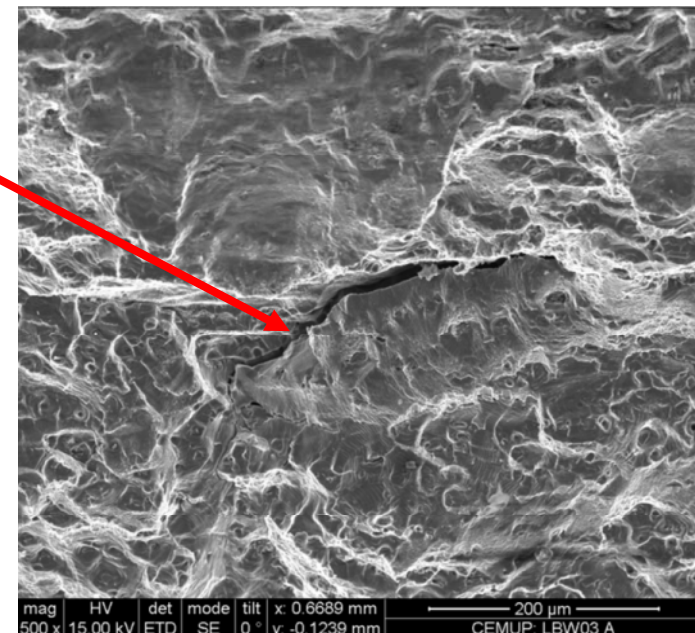
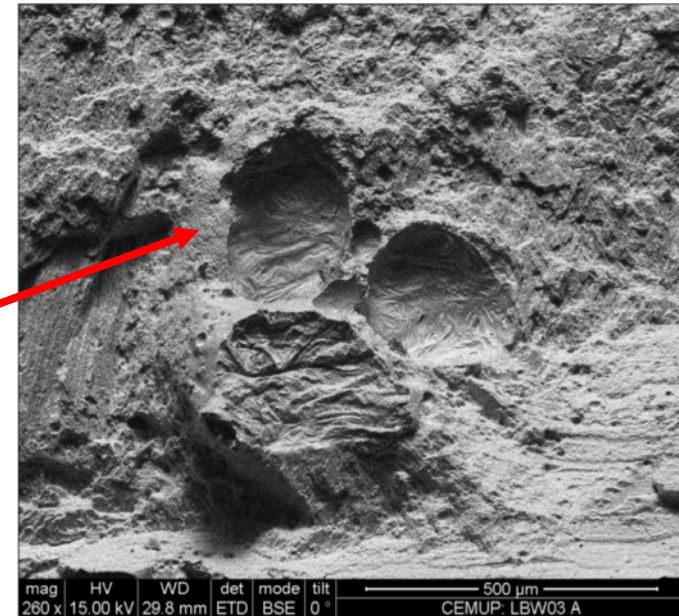
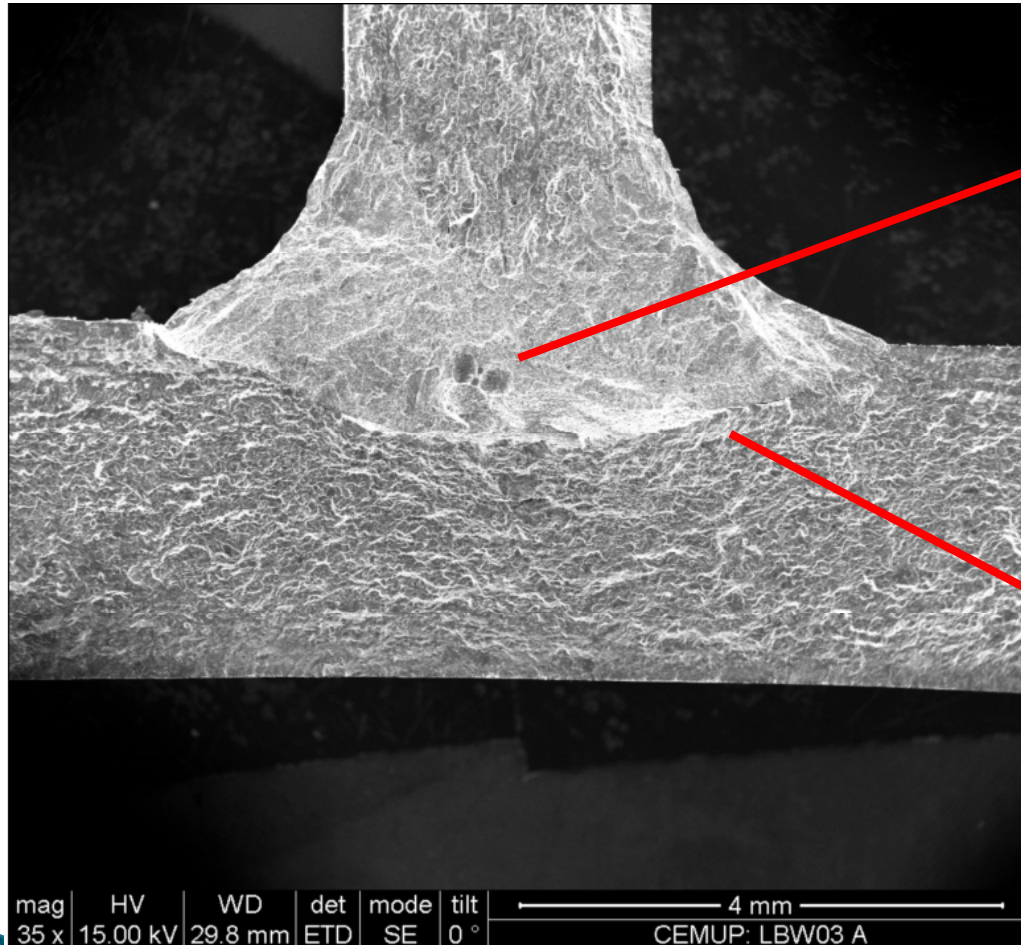


d) specimen FSW09



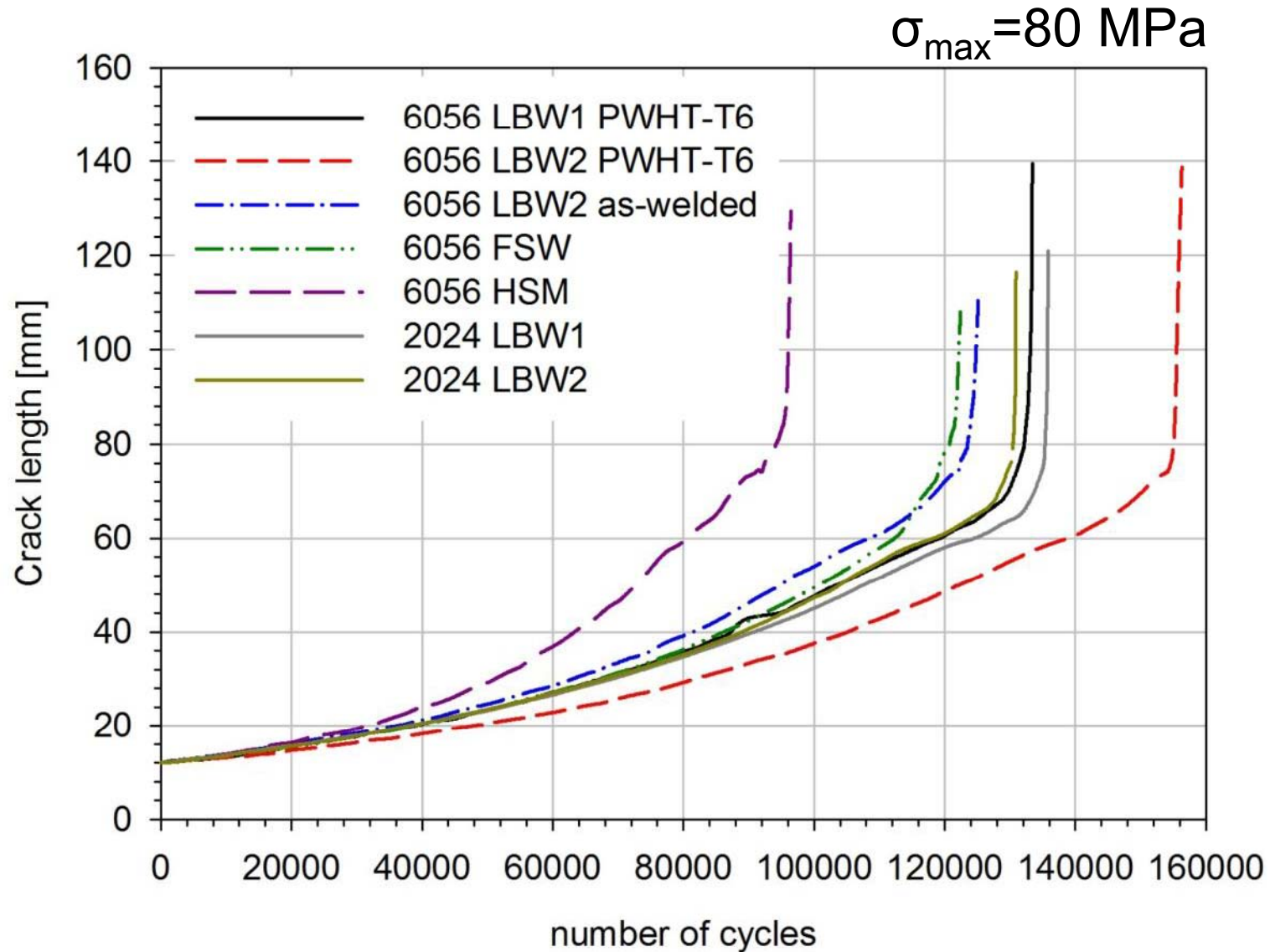
SEM ANALYSIS

Fracture Surfaces



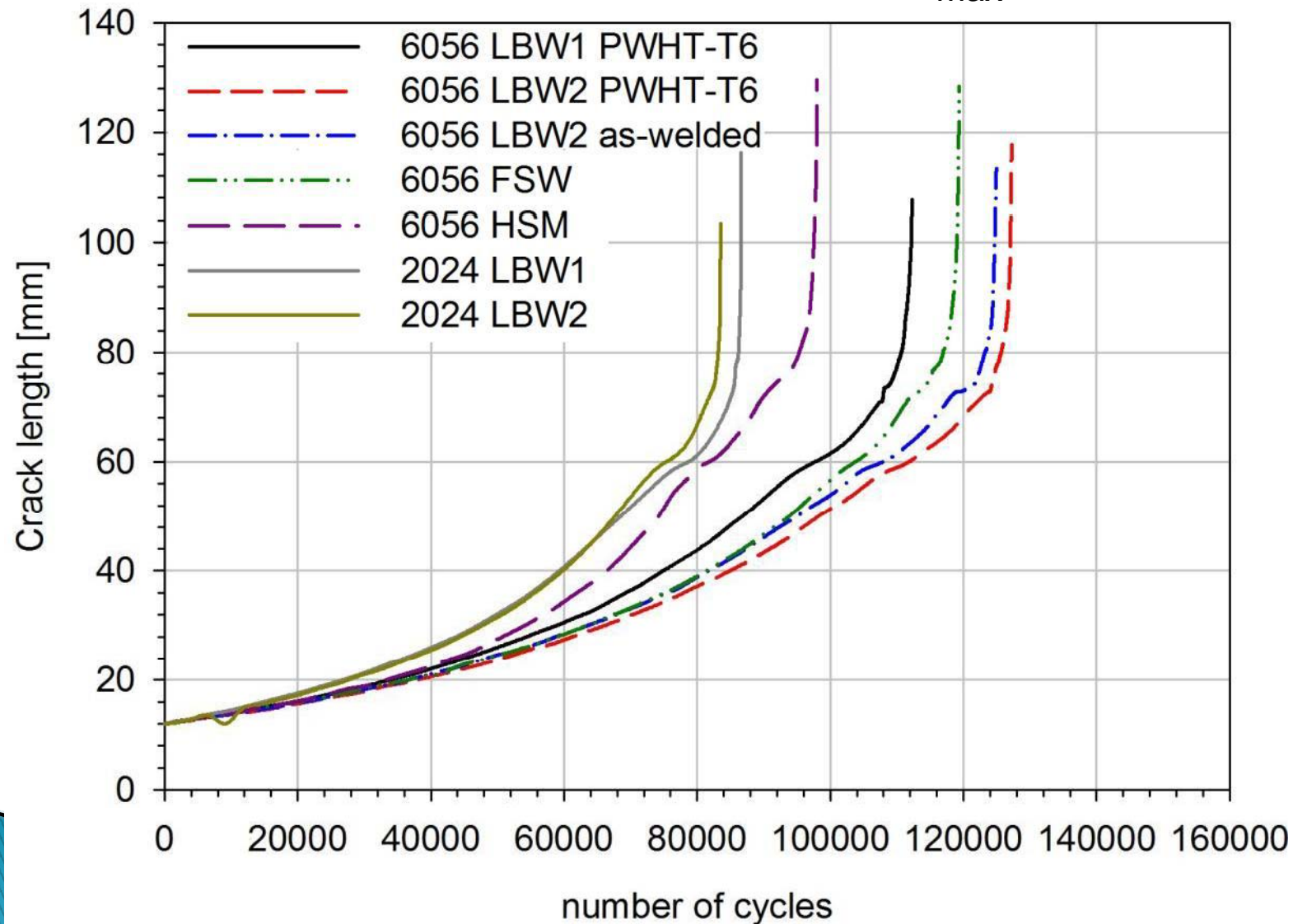
LBW1 6056 PWHT-T6 80MPa R=0,1

Experimental results– Crack growth for R=0.1



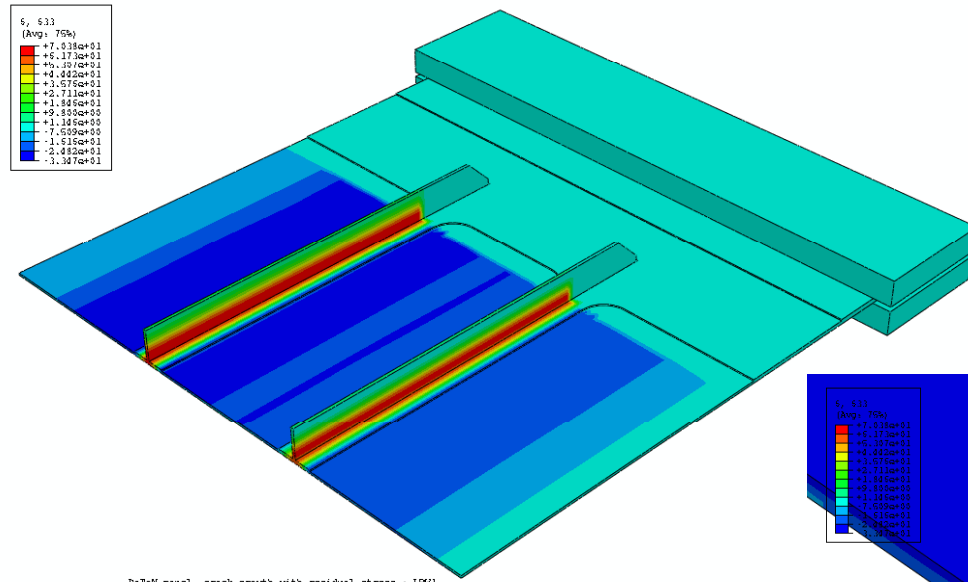
Experimental results– Crack growth for R=0.5

$\sigma_{\max}=110$ MPa



Finite Element Model with Residual Stress

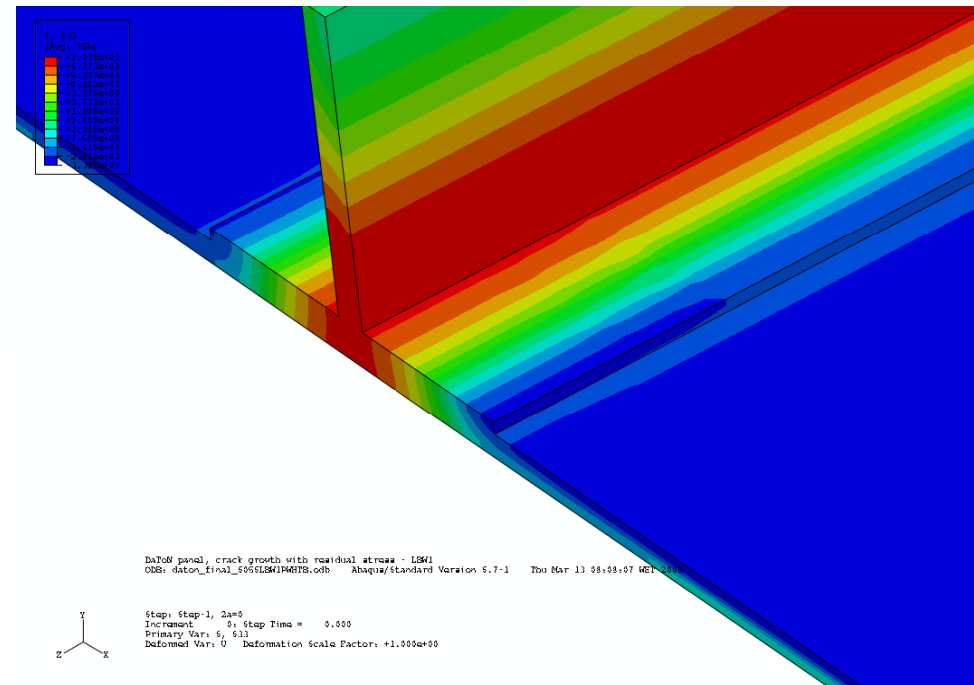
- Initial stress field – 6056 LBW1 PWHT



DaToN panel, crack growth with residual stress - LSW1
ODB: daton_final_6056LSW1PWHTS.odb Abaqus/Standard Version 6.7-1 Thu Mar 13 08:08:07 MET 2008



Step: Step-1, 2a=0
Increment: 0, Step Time = 0.000
Primary Var: ϵ_{xx}
Deformed Var: 0 Deformation Scale Factor: +1.000e+00



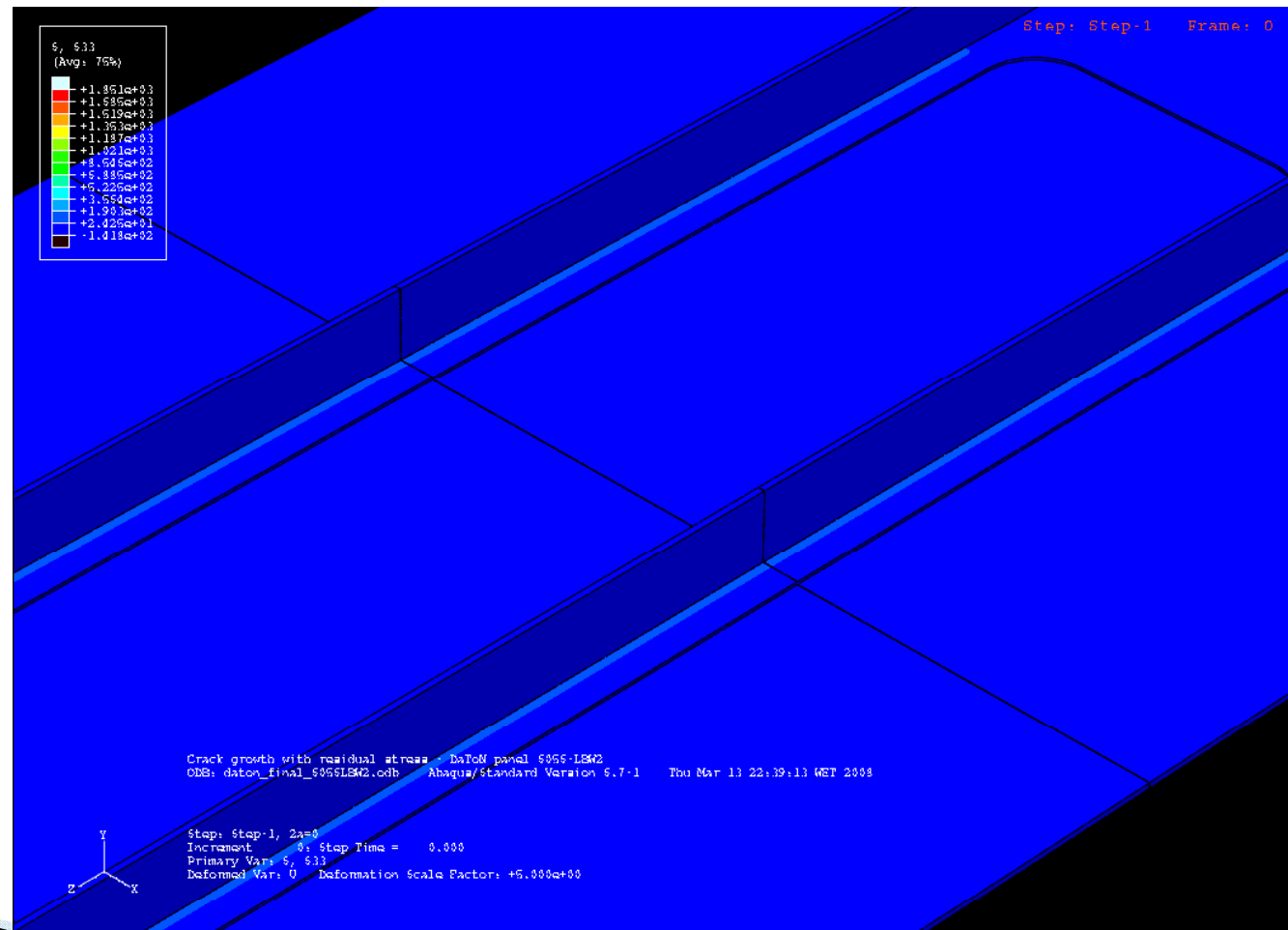
DaToN panel, crack growth with residual stress - LSW1
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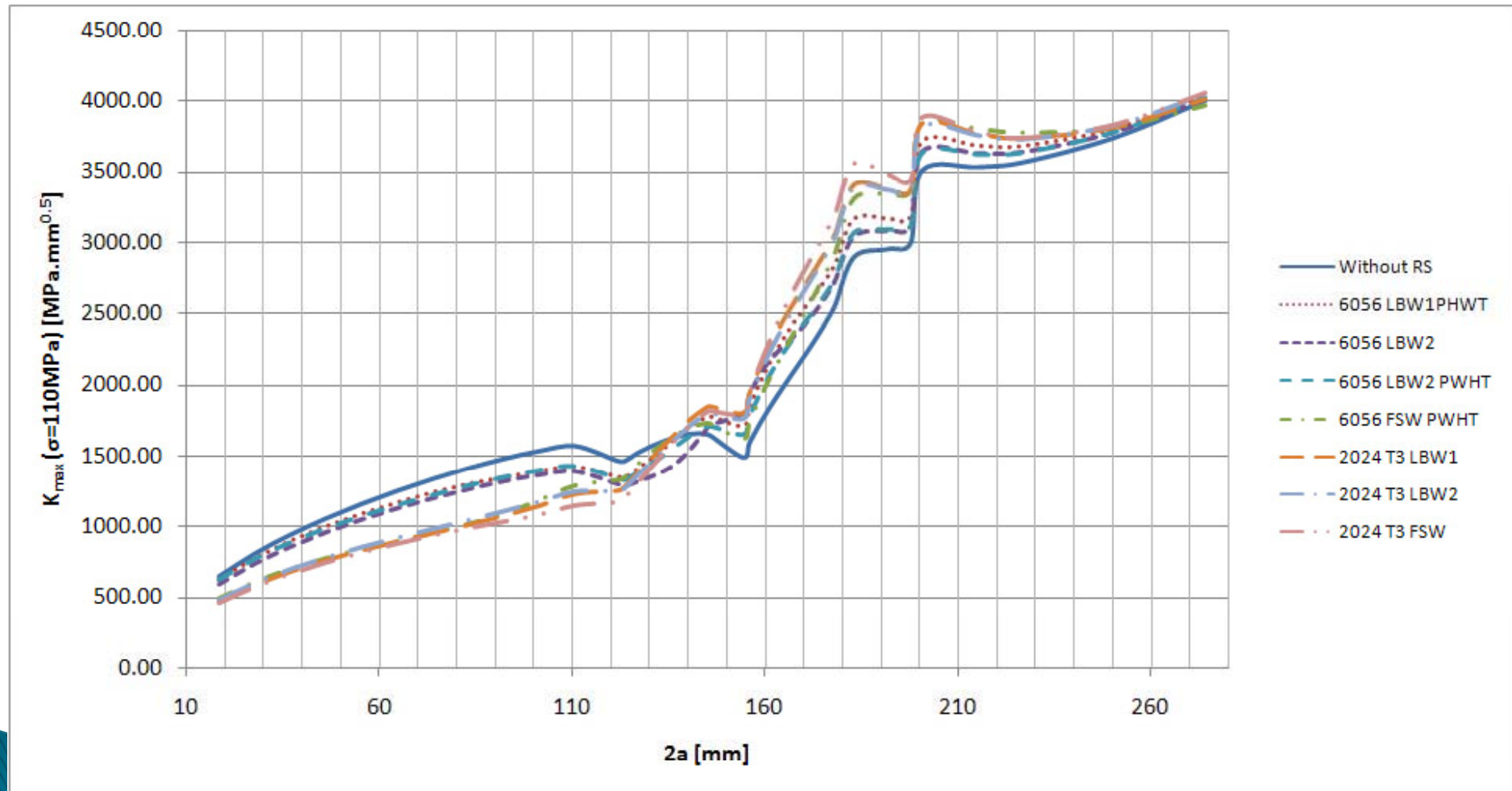
Finite Element Model with Residual Stress

- Stress field evaluation along crack growth



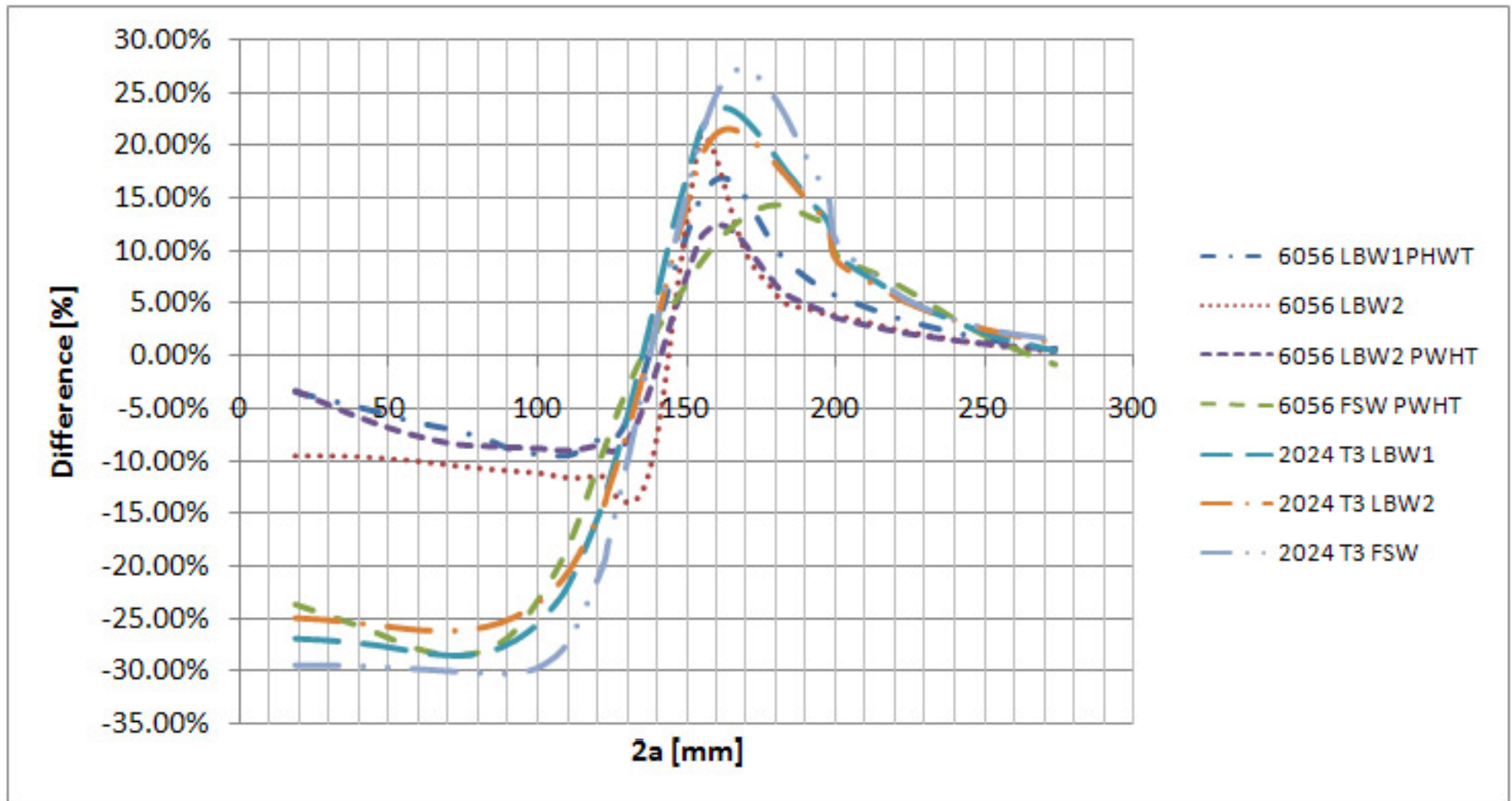
Stress Intensity Factors with modified VCCT for DaToN Panel

•SIF comparison – K_{\max} ($\sigma=110$ MPa)



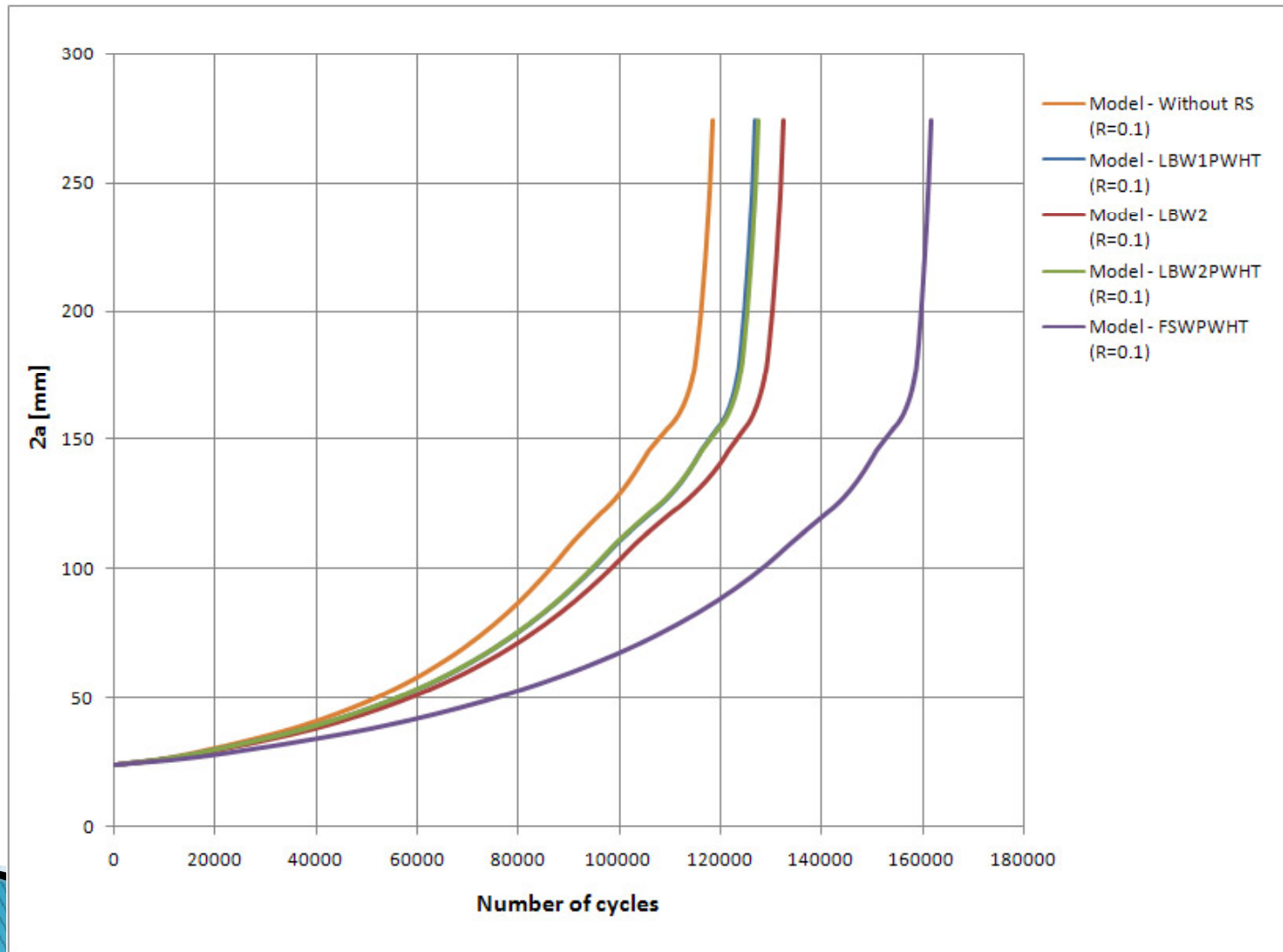
Stress Intensity Factors with modified VCCT

$$\bullet (K_{\max} \text{ with resid. stress} - K_{\max} \text{ without resid. stress}) / K_{\max} \text{ without resid. stress}$$



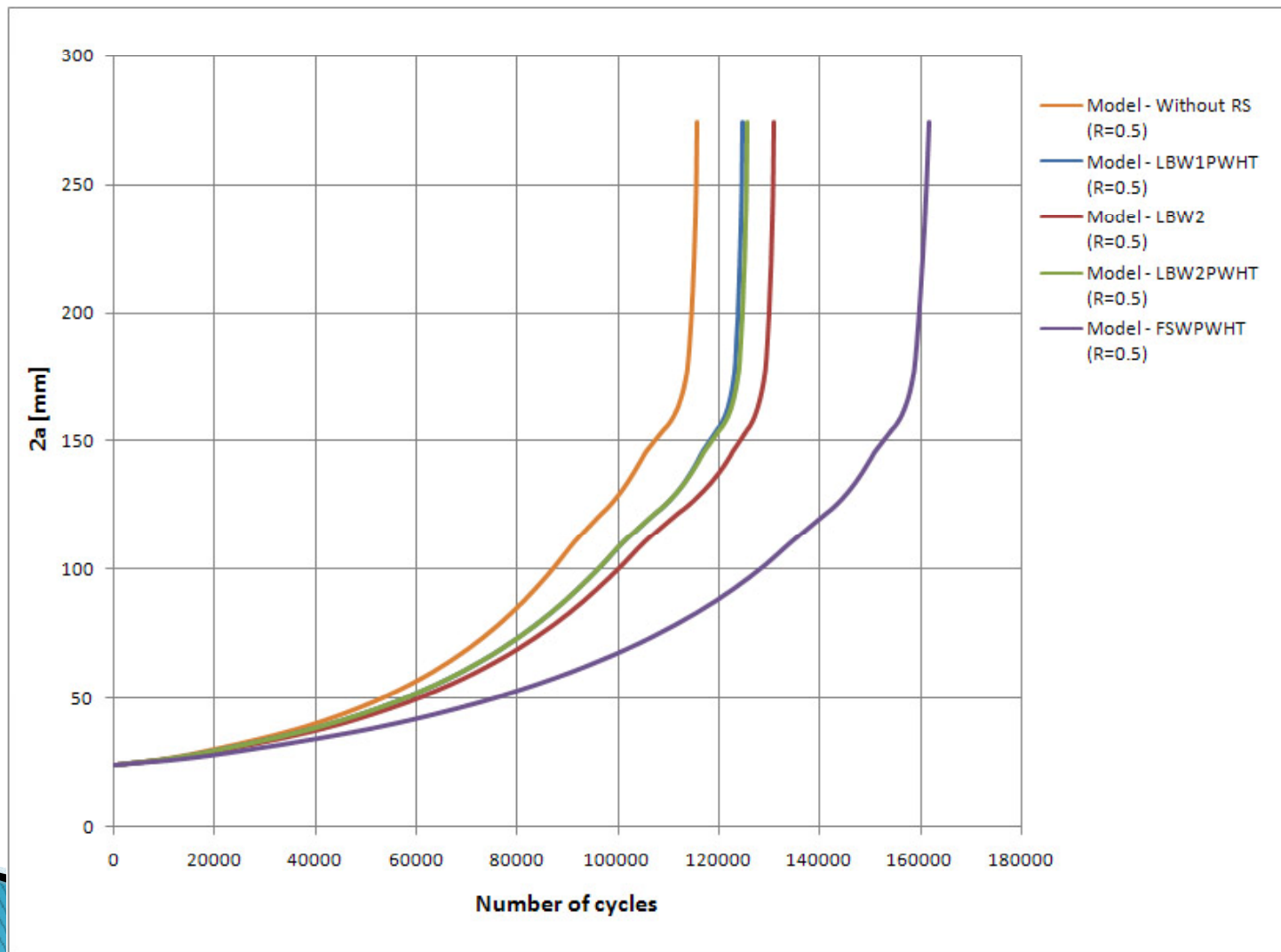
Models – crack growth AA6056 Panels – R=0.1

$$\sigma_{\max}=80 \text{ MPa}$$



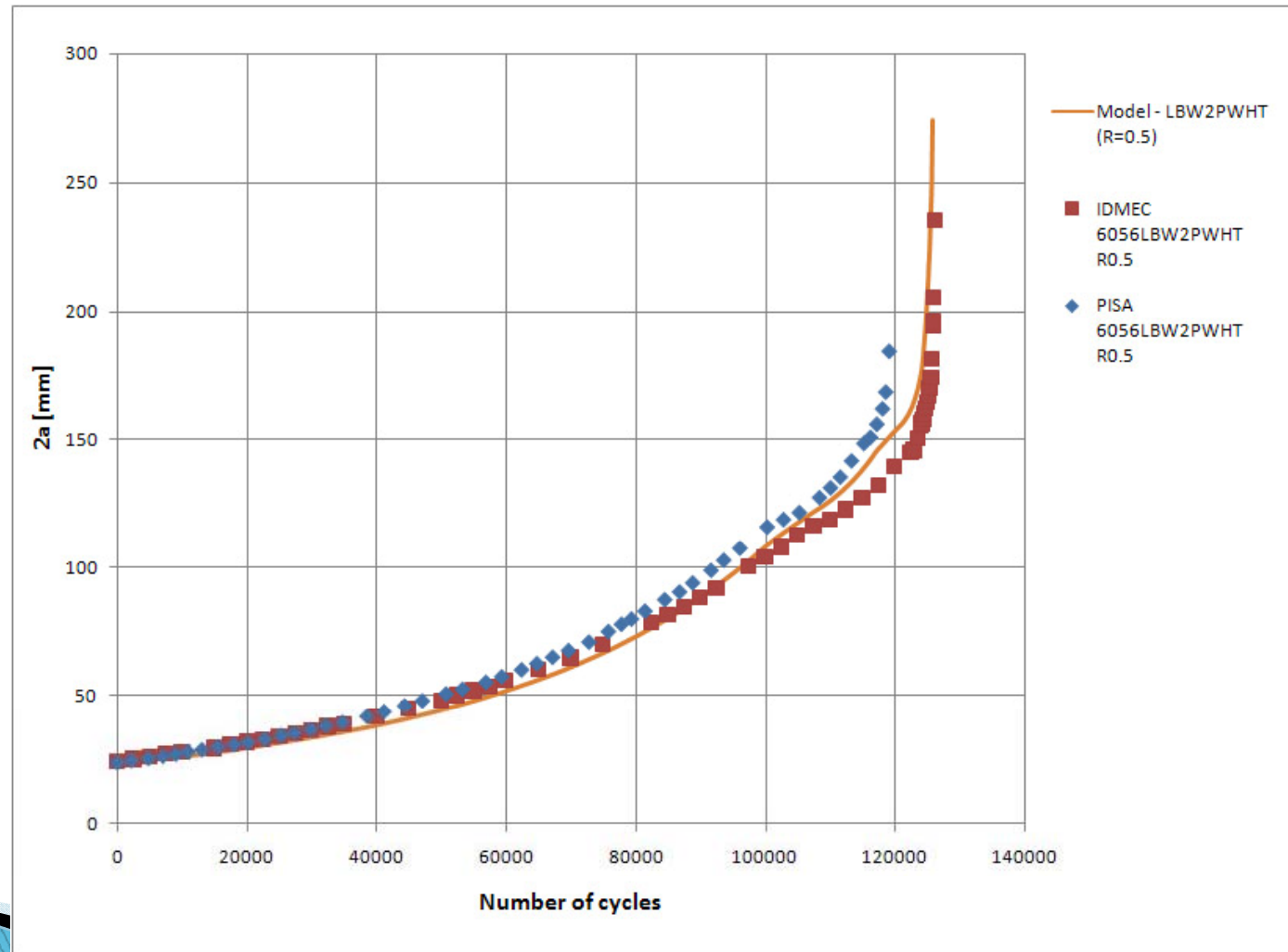
Models – Crack growth AA6056 Panels – R=0.5

$$\sigma_{\max}=110 \text{ MPa}$$



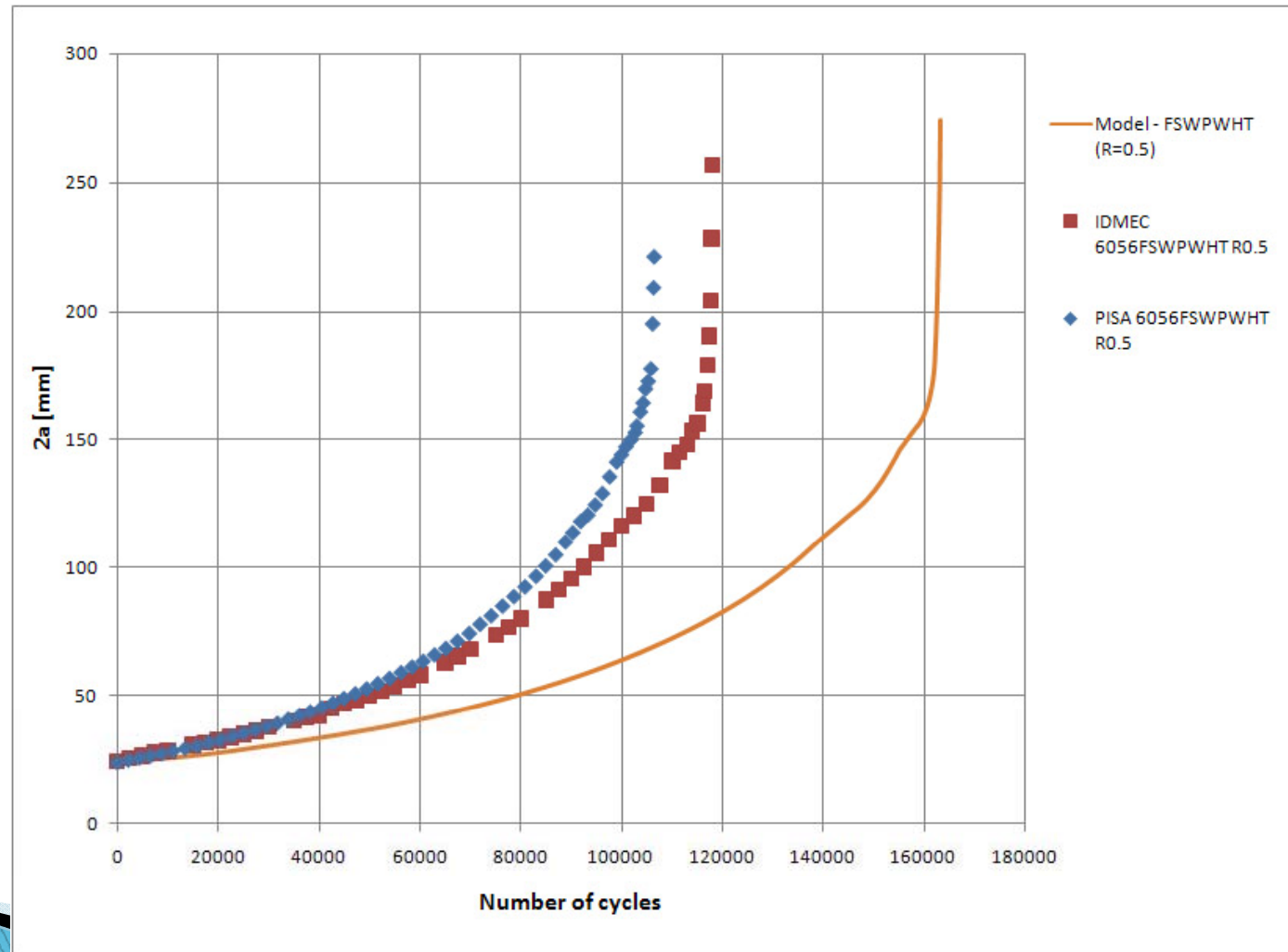
Crack growth – Comparison with experimental results

➤ AA6056 LBW2 PWHT R=0.5



Crack growth – Comparison with experimental results

➤ AA6056 FSW PWHT R=0.5



Conclusions

- ▶ New manufacturing process for aluminum alloys can simplify the fuselage configurations and reduce the weight of these structures;
- ▶ The manufacturing processes used in the DaToN project to produce stiffened panels promote residual stresses that can be beneficial or detrimental for the fatigue life depending upon where the crack starts to grow;
- ▶ The presented numerical models can estimate the effect of these processes in the fatigue life with reasonable accuracy; however in some cases the fatigue life was overestimated because of the compressive residual stress field in the middle of the panel.
- ▶ These new manufacturing processes conjugated with the new alloys can improve significantly the performance of the aircraft structures.



**Thank you for your
attention!**

