# Automated fatigue strength assessment of steel joints with weld ends in automotive design according to the Peak Stress Method

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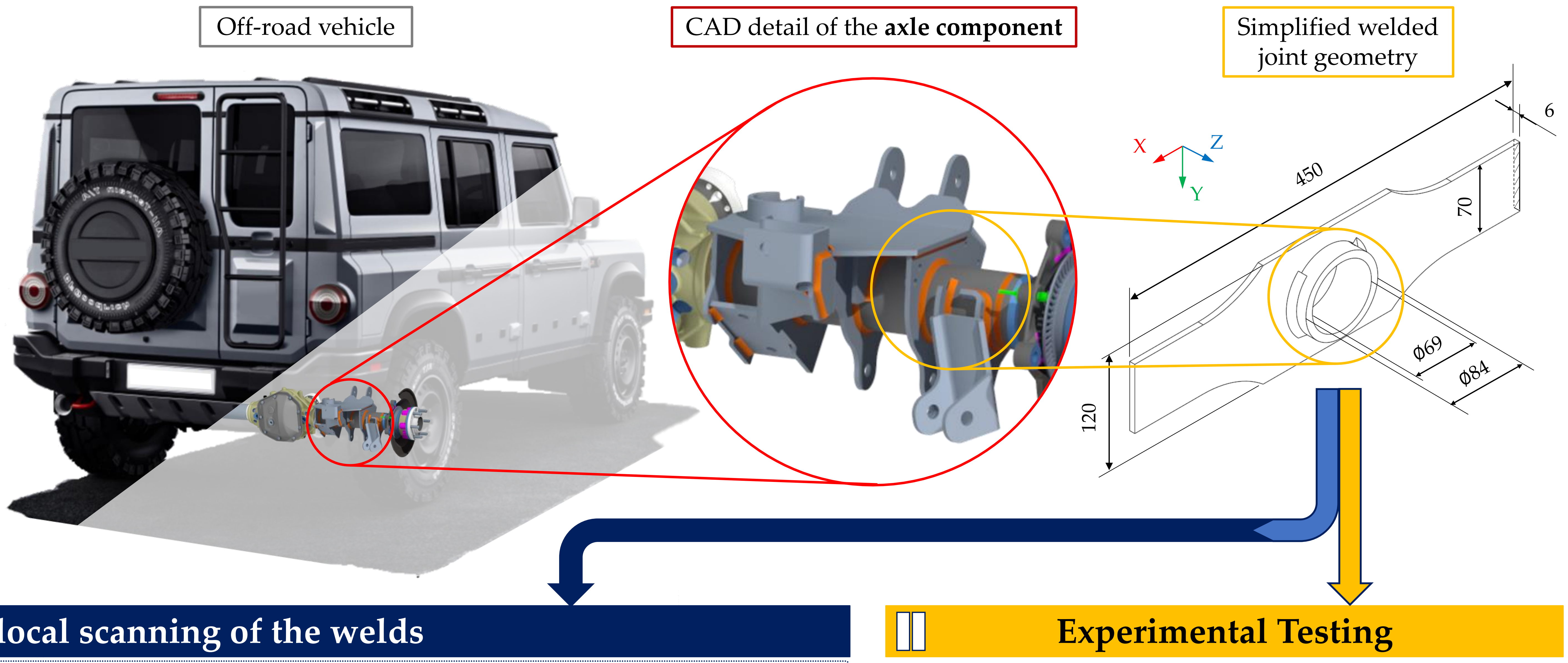
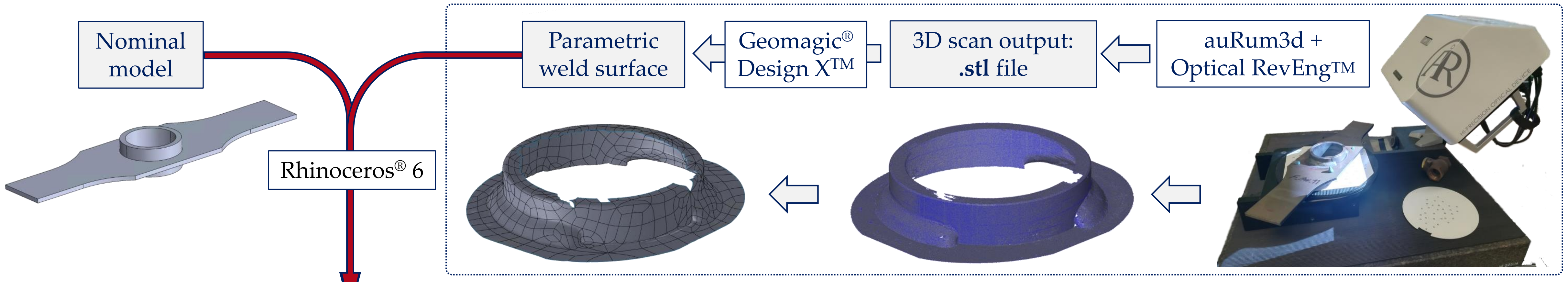
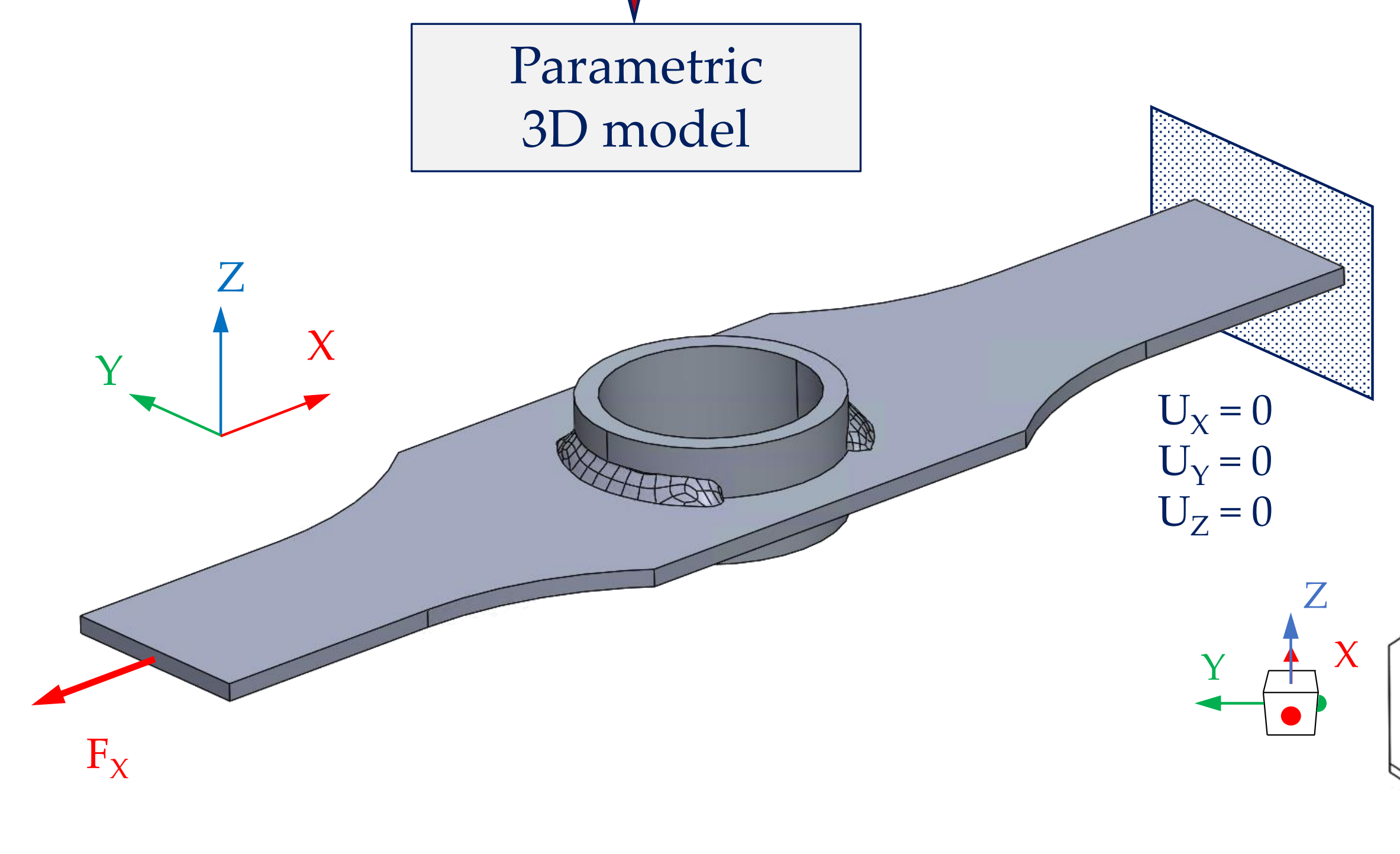
## Research Background & Aim

The complexity of the mechanical components is increasing year by year. In off-road vehicles, the suspension group is of primary importance in order to ensure the performances of the vehicle and grant a solid structure. In this perspective, a simplified joint geometry has been developed in order to capture the detail of the welds between the tube and the brackets of the **axle** and to assess the fatigue behaviour of the welded connections. In the framework of the fatigue assessment of steel welded components, the Peak Stress Method (PSM) allows to rapidly estimate the fatigue crack initiation point and the fatigue life of complex components under multiaxial stress states. A **reverse engineering method** has been employed to digitalize the local geometry of the welds by means of an optical 3D scanner. The digitalized geometry of the welds has been introduced in a FE model and automated PSM analyses have been performed by means of a dedicated analysis tool developed in **Ansys® Mechanical** using **Ansys® ACT**. **The aim of this research** is to create a **digital twin** of the real steel welded joint by interfacing the experimental results with theoretical fatigue strength previsions.



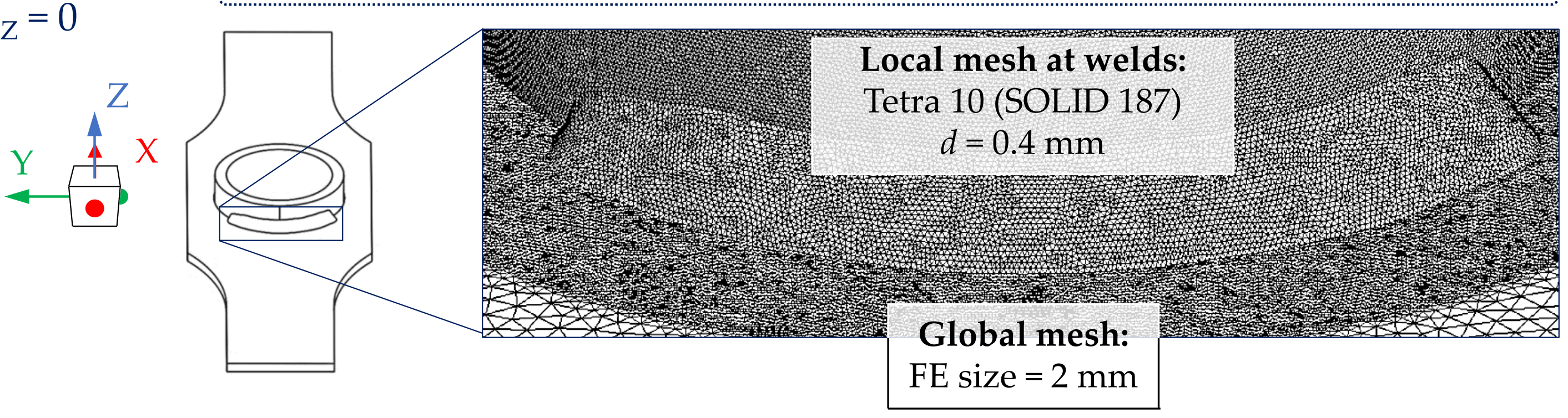
## 3D local scanning of the welds



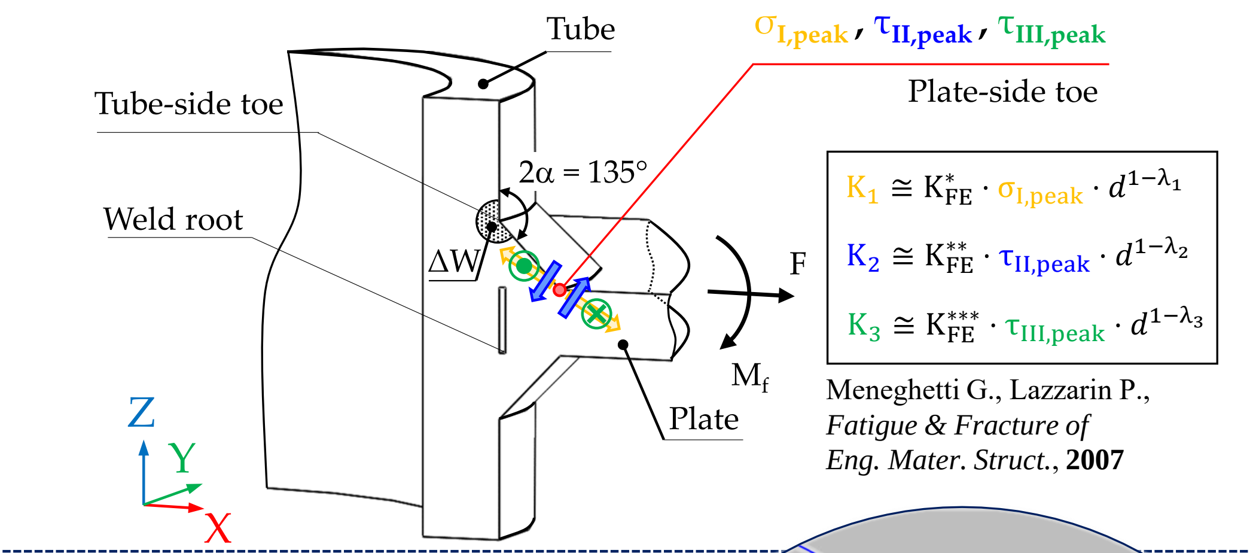


## FE model & analysis

The FE analysis was carried out in **Ansys® Mechanical**. A 10-node Tetra mesh having element size $d$ at the welds has been generated according to PSM mesh density requirement $a/d \leq 3$, $a$ being the ligament, i.e. difference between the plate thickness and two times the weld penetration of the considered joint. In order to fulfil PSM mesh density prescription, a local element size $d$ = 0.4 mm has been adopted. Moreover, a global mesh of element size $d$ = 2 mm has been generated for the rest of the model.



## Automated fatigue strength assessment according to the PSM



$$K_1 \cong K^{*}_{FE} \cdot \sigma_{I,peak} \cdot d^{1-\lambda_1}$$
$$K_2 \cong K^{**}_{FE} \cdot \tau_{II,peak} \cdot d^{1-\lambda_2}$$
$$K_3 \cong K^{***}_{FE} \cdot \tau_{III,peak} \cdot d^{1-\lambda_3}$$

Meneghetti G., Lazzarin P., *Fatigue & Fracture of Eng. Mater. Struct.*, **2007**

$$\Delta\bar{W} = c_{W,1}\frac{e_1}{E}\left[\frac{\Delta K_1}{R_0{}^{1-\lambda_1}}\right]^2 + c_{W,2}\frac{e_2}{E}\left[\frac{\Delta K_2}{R_0{}^{1-\lambda_2}}\right]^2 + c_{W,3}\frac{e_3}{E}\left[\frac{\Delta K_3}{R_0{}^{1-\lambda_3}}\right]^2$$

$$\Delta\bar{W} = \frac{1-\nu^2}{2E} \cdot \Delta\sigma^2_{eq,peak}$$

Lazzarin P. *et al.* *Eng. Fract. Mech.*, **2008**

$$\Delta\sigma_{eq,peak} = \sqrt{c_{w1} \cdot f^2_{w1} \cdot \Delta\sigma^2_{I,peak} + c_{w2} \cdot f^2_{w2} \cdot \Delta\tau^2_{II,peak} + c_{w3} \cdot f^2_{w3} \cdot \Delta\tau^2_{III,peak}}$$

$$\lambda = \frac{c_{w2} \cdot f^2_{w2} \cdot \Delta\tau^2_{II,peak} + c_{w3} \cdot f^2_{w3} \cdot \Delta\tau^2_{III,peak}}{c_{w1} \cdot f^2_{w1} \cdot \Delta\sigma^2_{I,peak}}$$

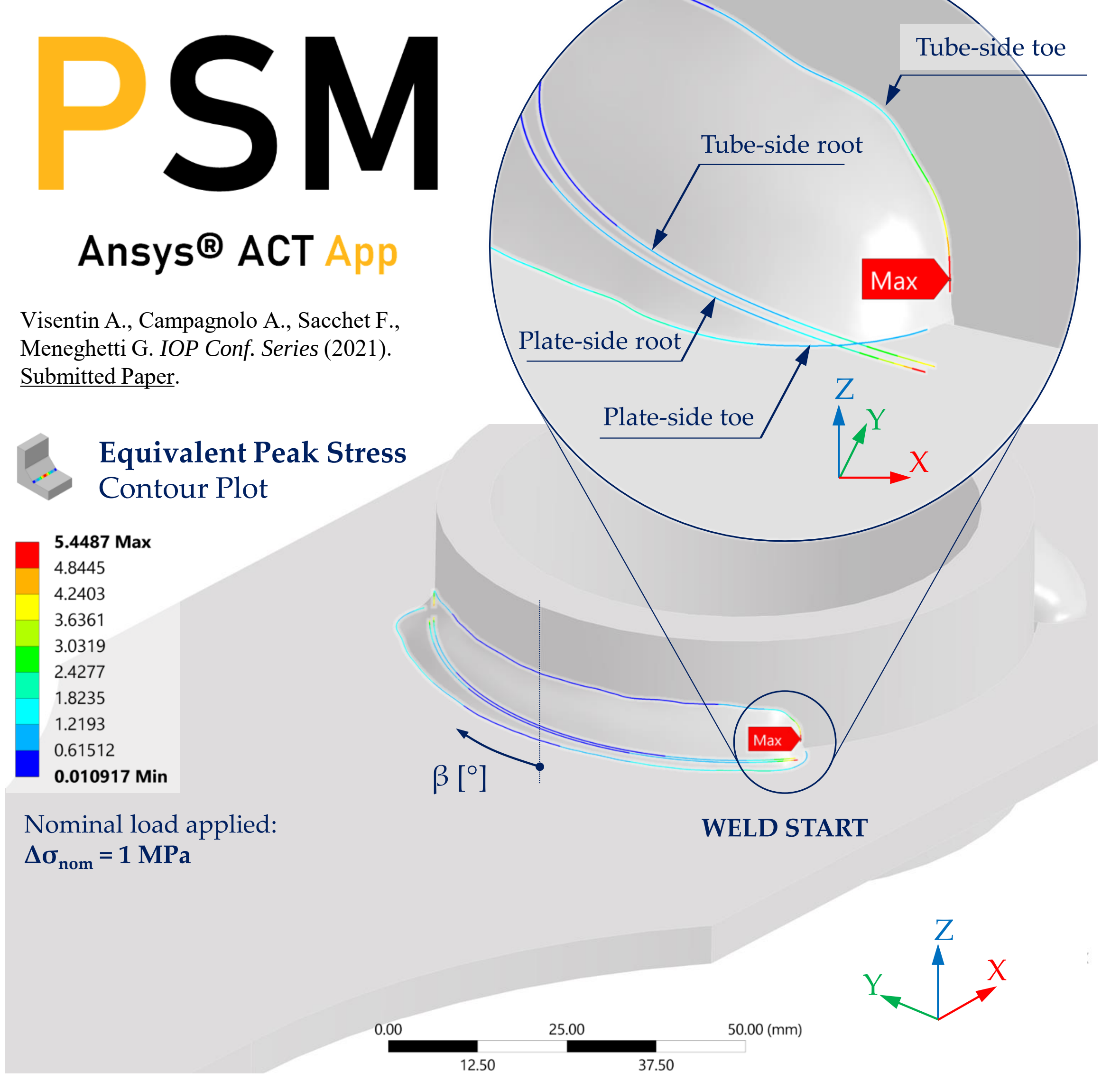
Fatigue life estimation

Meneghetti G., Campagnolo A., *Int. J of Fatigue*, **2020**

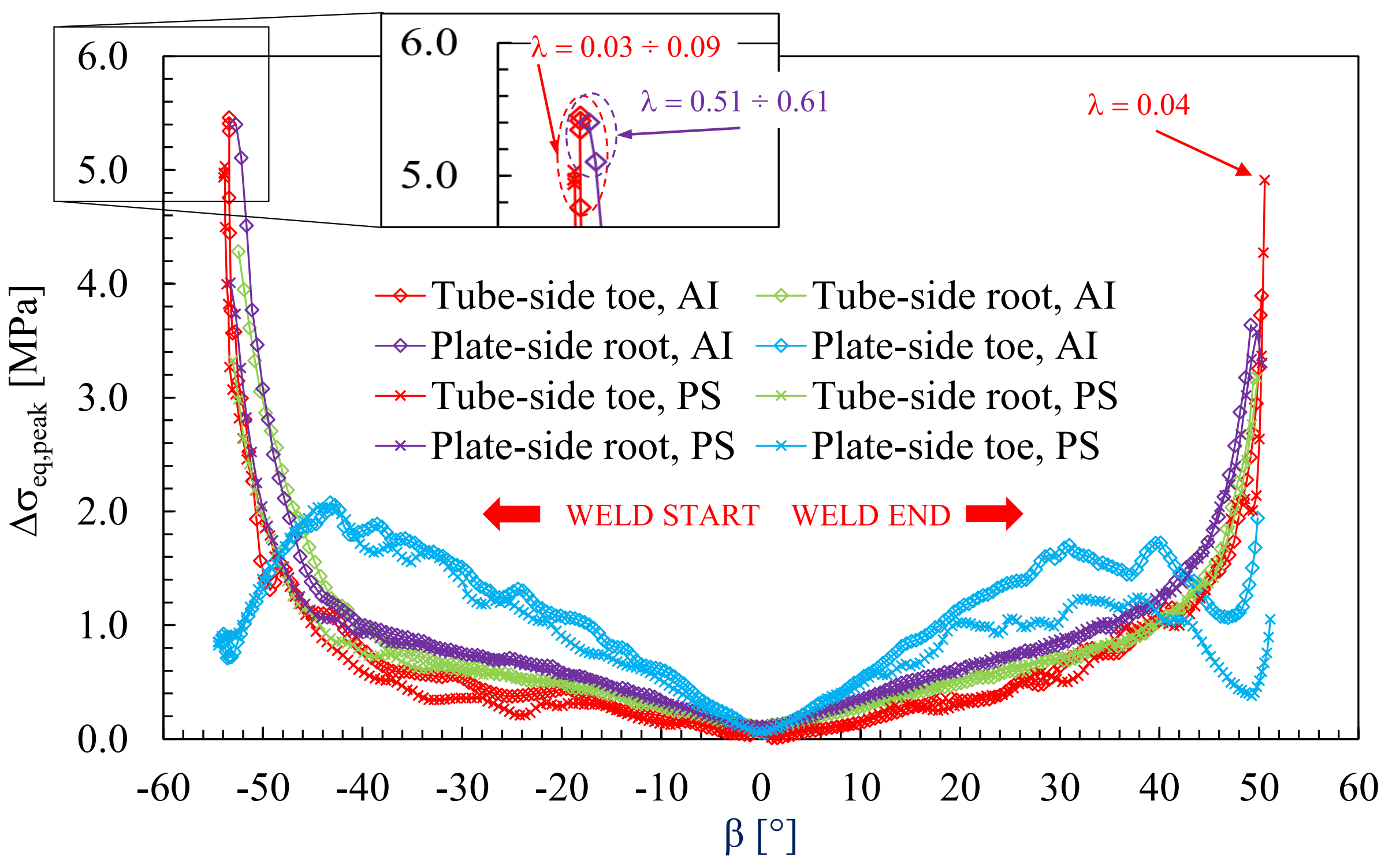
**PSM**

**Ansys® ACT App**

Visentin A., Campagnolo A., Sacchet F., Meneghetti G. *IOP Conf. Series* (2021). Submitted Paper.



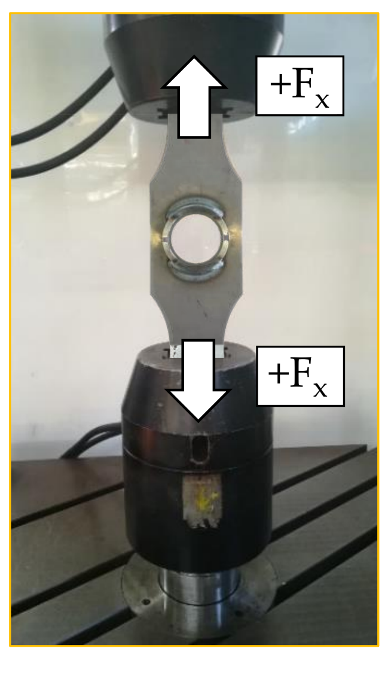
Nominal load applied:
$\Delta\sigma_{nom}$ = 1 MPa

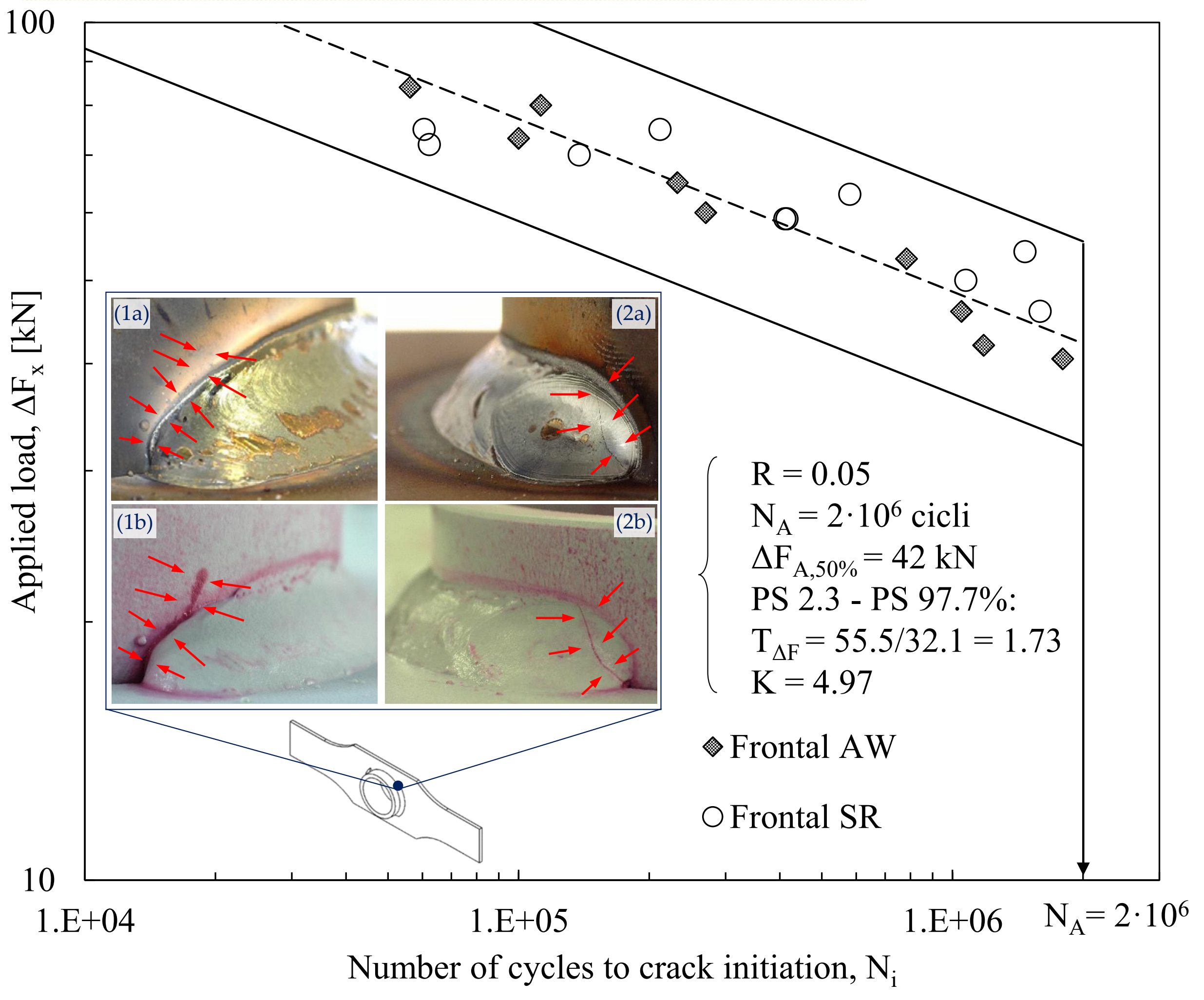


The **automated PSM analysis** allows to correctly estimate the crack initiation point, identified by the maximum $\Delta\sigma_{eq,peak}$ value at the weld start of the tube-side toe. Moreover, non-negligible $\Delta\sigma_{eq,peak}$ values have also been detected at the weld end of the tube-side toe, where, however, no cracks have been detected from the experimental fatigue tests. The experimental data has been converted from nominal stress range $\Delta\sigma_{nom}$ to equivalent peak stress range $\Delta\sigma_{eq,peak}$ and compared with the proper PSM design scatter band, according to the value of the local biaxial ratio λ.

## Experimental Testing

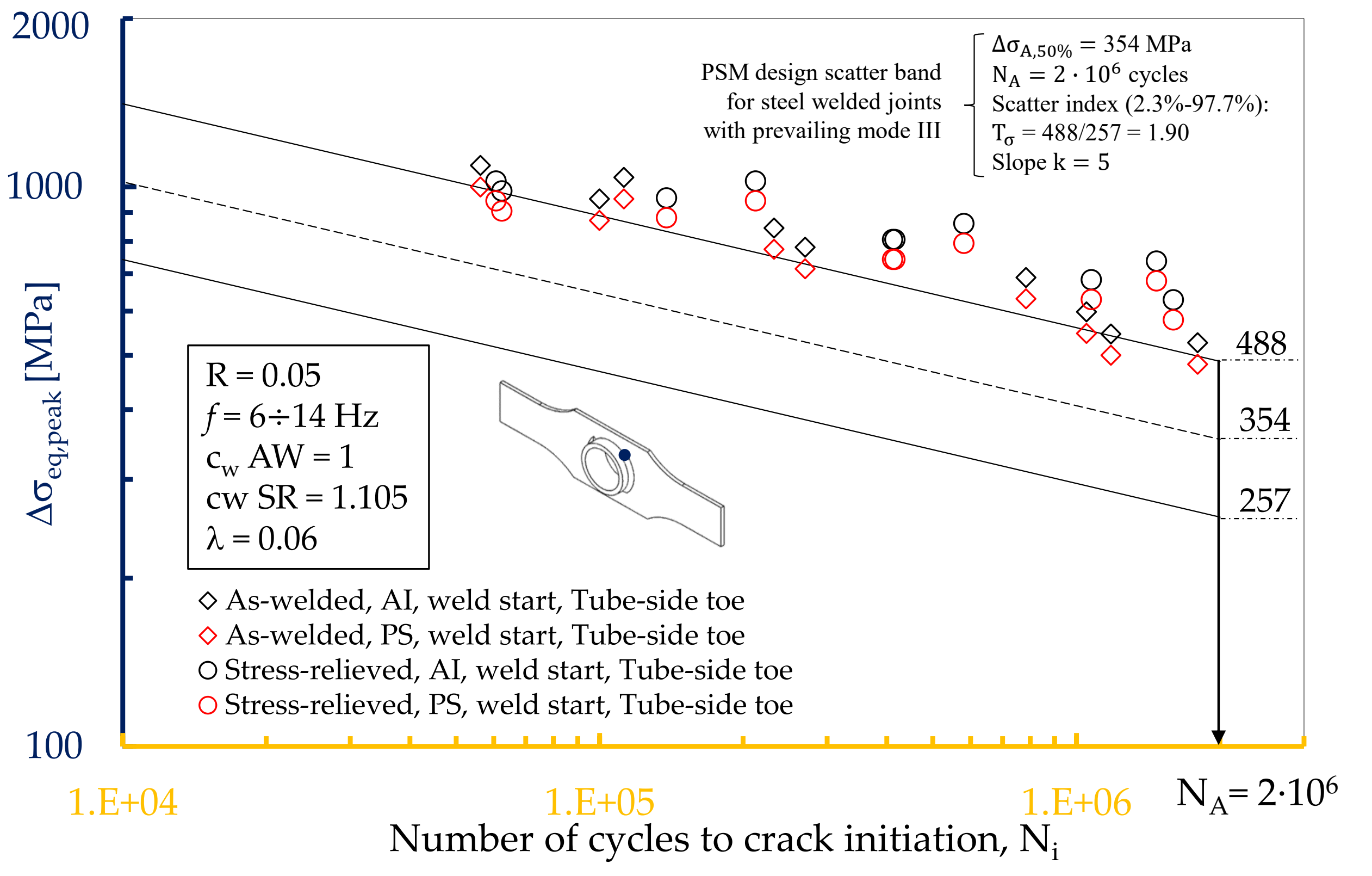
The joints, both as-welded (AW) and stress-relieved (SR), were fatigue tested by means of a MTS uniaxial fatigue testing machine. The applied load induces multiaxial stress conditions both at weld toe and at weld root. The main crack initiation site is located at the **weld start on the tube-side toe** as shown in (1a) and (1b) through the results of non-destructive investigations performed using dye penetrant inspection. Another crack initiation site is located at the **weld end on the root** as shown in (2a) and (2b). A statistical analysis has been carried out on the experimental data and a nominal stress-based scatter band having slope k = 4.97 has been obtained.





## Discussion and conclusions

The local geometry of the welds has been virtualized using a 3D scanner in order to be introduced in the FE model. The PSM allows to predict the main crack initiation site, in agreement with experimental evidences. Moreover, the PSM estimated the fatigue life of the welded joints on the safe side. Fatigue life results proposed below have been estimated with respect to two different welds among the four scanned ones, i.e. AI (front-lower side) and PS (back-upper side). This provides a first insight on the effect of the welding process variability of the welds geometry on the fatigue strength of the joint, in terms of equivalent peak stress $\Delta\sigma_{eq,peak}$ at the crack initiation point.



## References

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