Finite Element Analyses of steel welded joints using the Peak Stress Method

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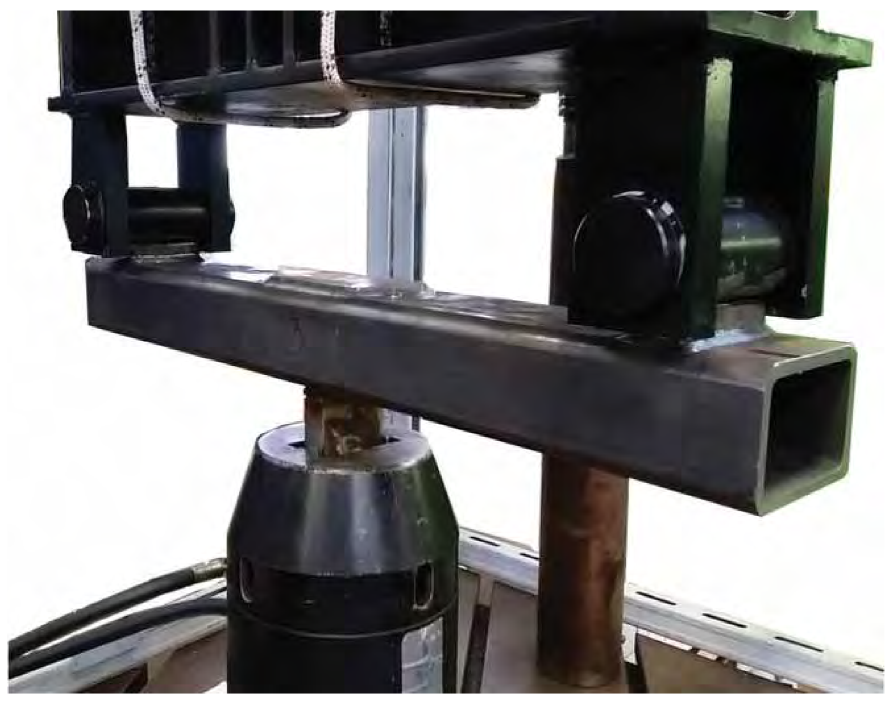


Welded joint clamped in the fatigue machine.

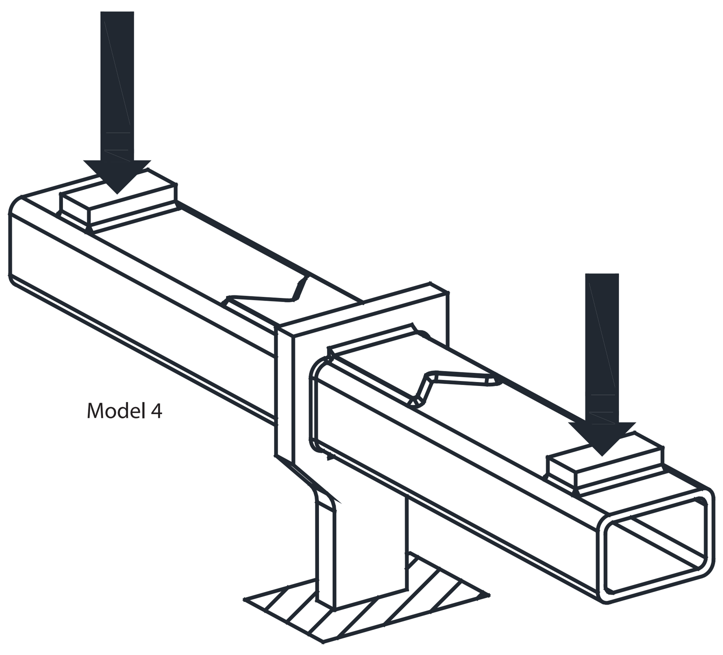
Introduction

In recent years a new methodology has been proposed to assess the fatigue resistance of steel welded joints. The so called Peak Stress Method (PSM) allows the application of the N-SIFs method through simple, linear-elastic FE analyses. The objective of this work was to verify the applicability of the PSM to complex 3D geometries of steel welded joints.

Steel welded joint completely failed due to fatigue testing with a load ratio equal to 0.1. Crack propagation started from the root of the weld bead connecting the brace to the central plate.

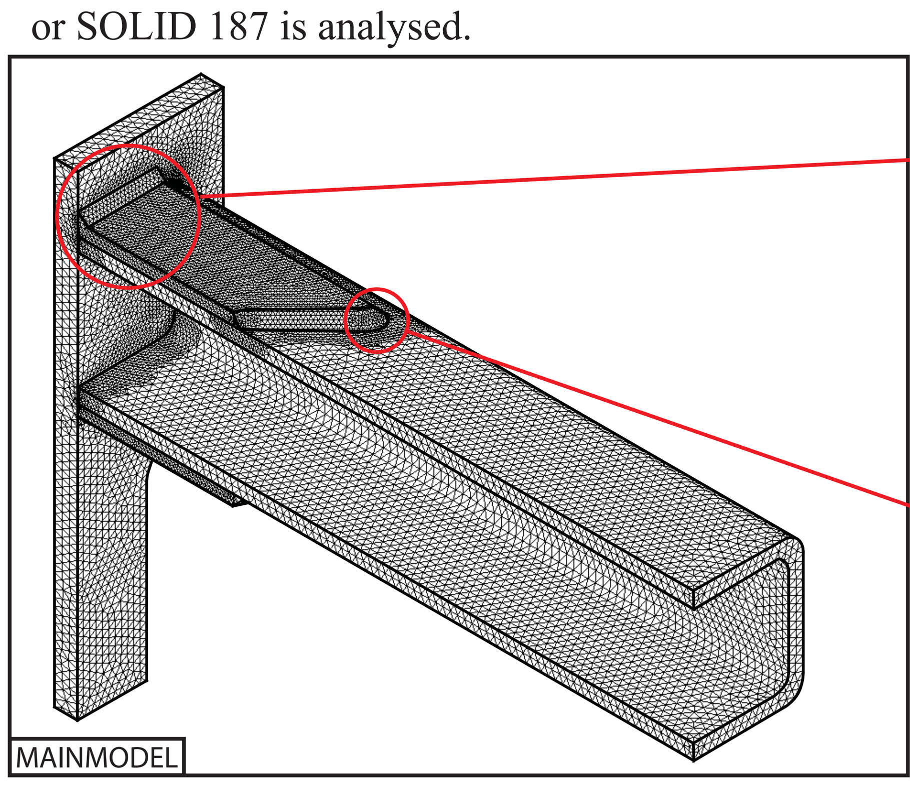
Fatigue crack at weld toe.

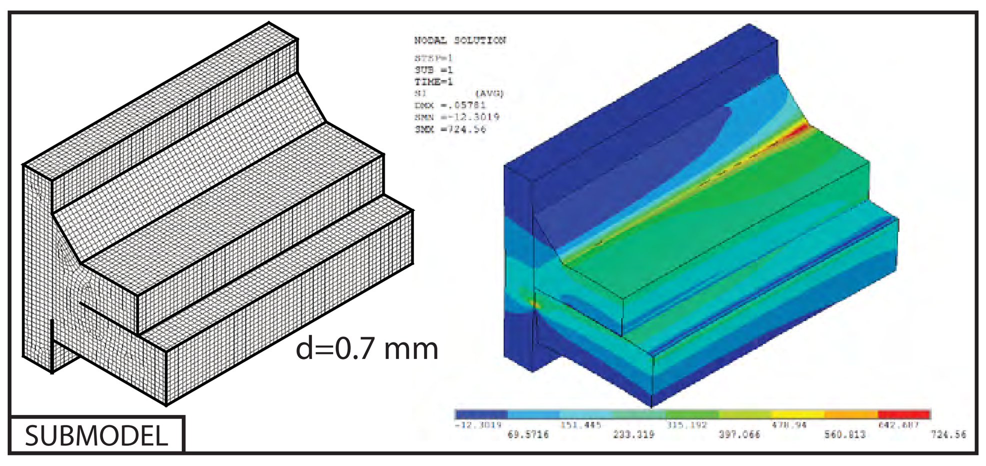
Method

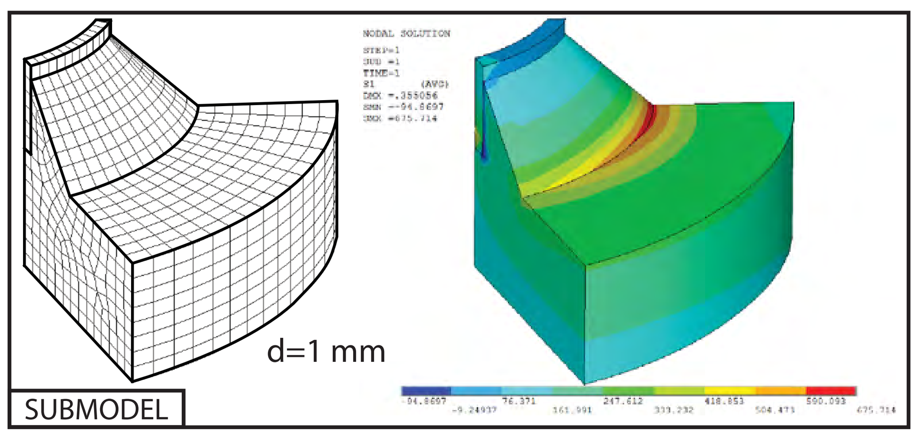


Coarse meshes obtained with the ANSYS® free mesh algorithm are used to calculate the peak stress at the tip of weld root/toe cracks.

As first step, a 3D model meshed with SOLID 186 or SOLID 187 is analysed.

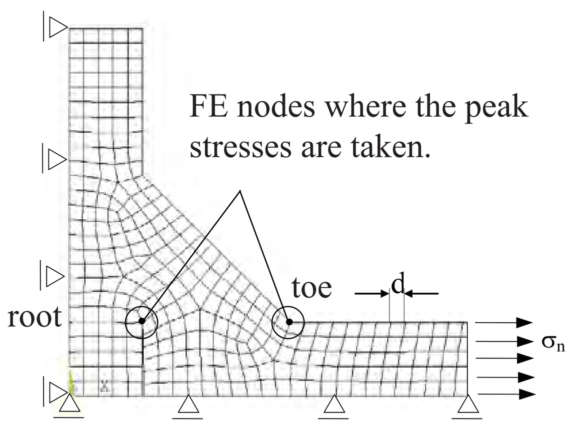






Once the main model has been analysed, submodels are cut out. To obtain the correct elements pattern a 2D mesh is created and then extruded using SOLID 185 elements. The free mesh algorithm implemented in ANSYS® has to be used to create the 2D mesh. The only parameter necessary to control the mesh is the "global element size" (called "d" in the pictures).

In case of multiple crack initiation points different submodels can be created.



Typical 2D free mesh applied to a load-carrying fillet-welded joint to calculate the fatigue strength according to the PSM. This mesh can be extruded using SOLID185 along the normal direction or along the weld toe in order to obtain a 3D submodel.

2α (deg)	$f_{w1, d=0.5\ mm}$	$f_{w1, d=1\ mm}$
0	0.9970	1.410
90	1.015	1.392
135	0.8490	1.064
150	0.7618	0.9047

2α (deg)	$f_{w2, d=0.5\ mm}$	$f_{w2, d=1\ mm}$
0	3.904	5.522

Peak stresses obtained from the submodels can be converted into an equivalent peak stress using the following formula:

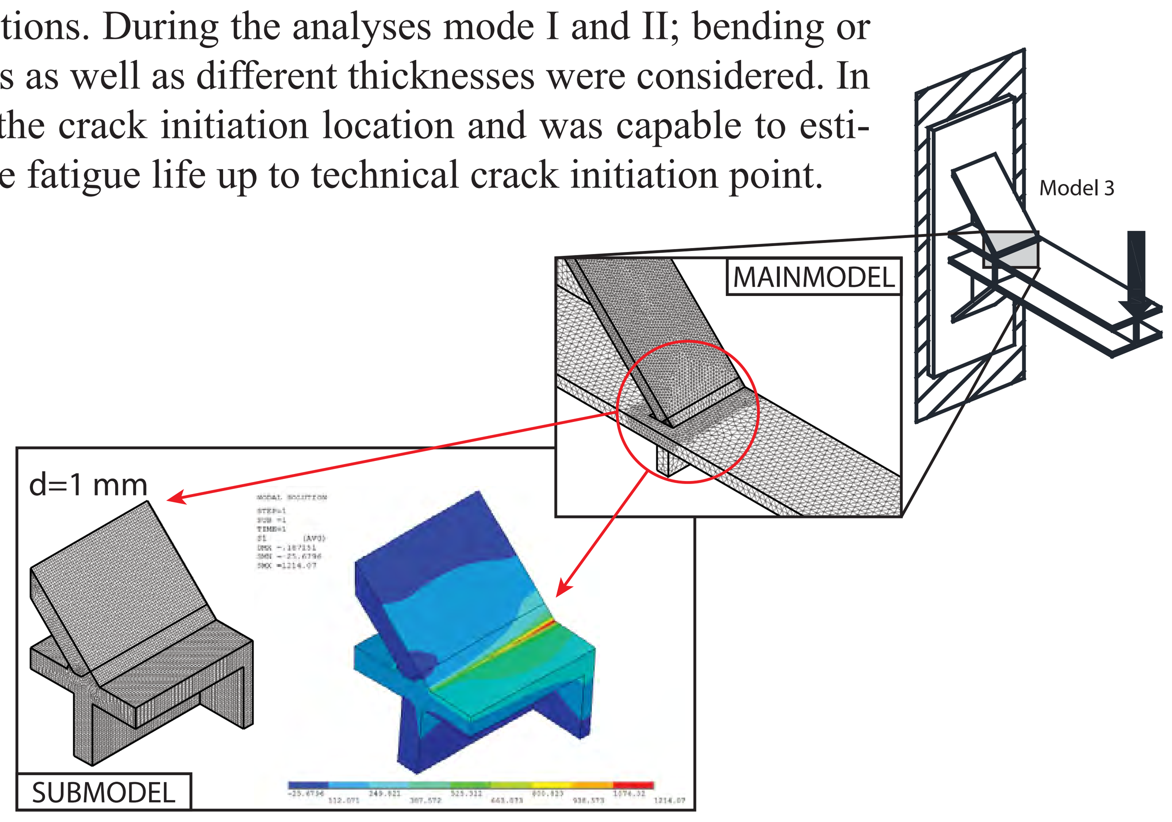
$$\Delta\sigma_{eq,peak} = \sqrt{f_{w1}^2 \cdot \Delta\sigma^2_{\theta\theta,\theta=0,peak} + f_{w2}^2 \cdot \Delta\tau^2_{r\theta,\theta=0,peak}}$$

The equivalent peak stress allows the comparison between different cracks, to single out the most critical one. Furthermore it allows the estimation of fatigue resistance.

Results

The proposed method has been applied to different welded joint geometries. All the analysed joints consisted of arc-welded 8- or 10-mm-thick structural steel plates or tubular elements. Peak stresses were extracted and converted to equivalent peak stresses using the proposed formula, these stresses are reported in the underlying graph. It should be noted that the PSM is a local approach based on the N-SIFs method and it is therefore suitable to assess the fatigue life up to crack initiation point. In complex joint geometries long cracks might develop outside the zone governed by the N-SIFs leading to long propagation phases.

The Peak Stress Method has been applied to rather complex joint geometries made of structural steel and tested in the as-welded conditions. During the analyses mode I and II; bending or axial loading; root and toe failures as well as different thicknesses were considered. In most cases the PSM singled out the crack initiation location and was capable to estimate with good approximation the fatigue life up to technical crack initiation point.



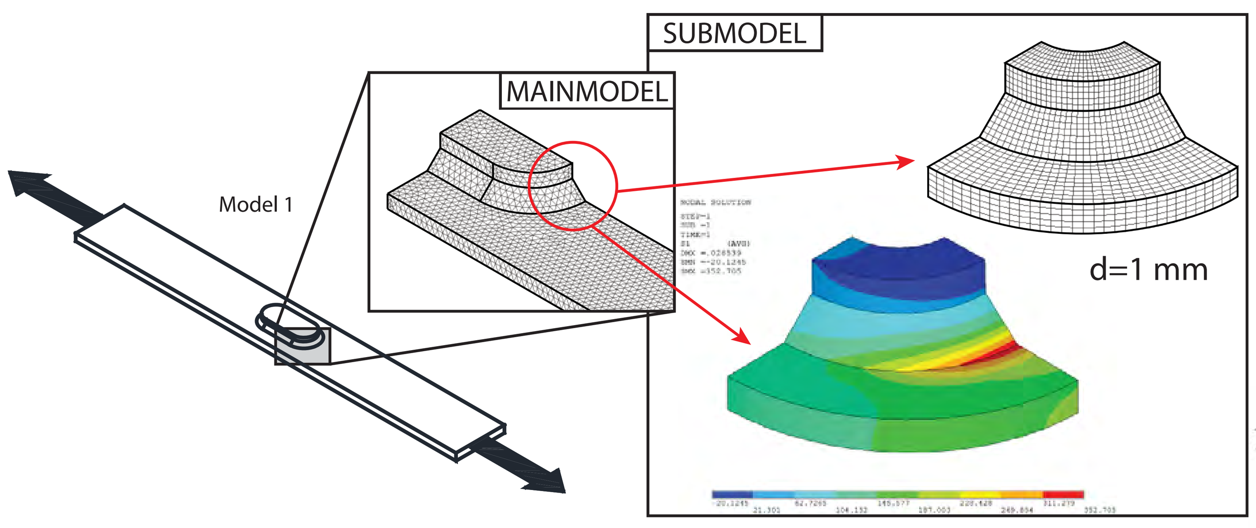
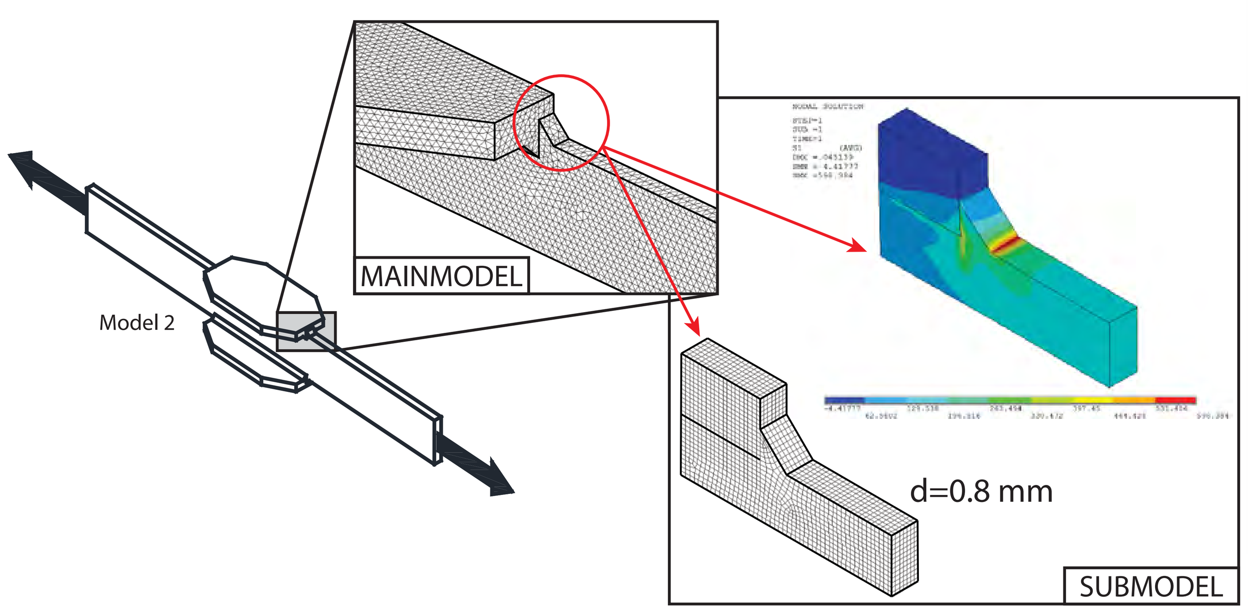
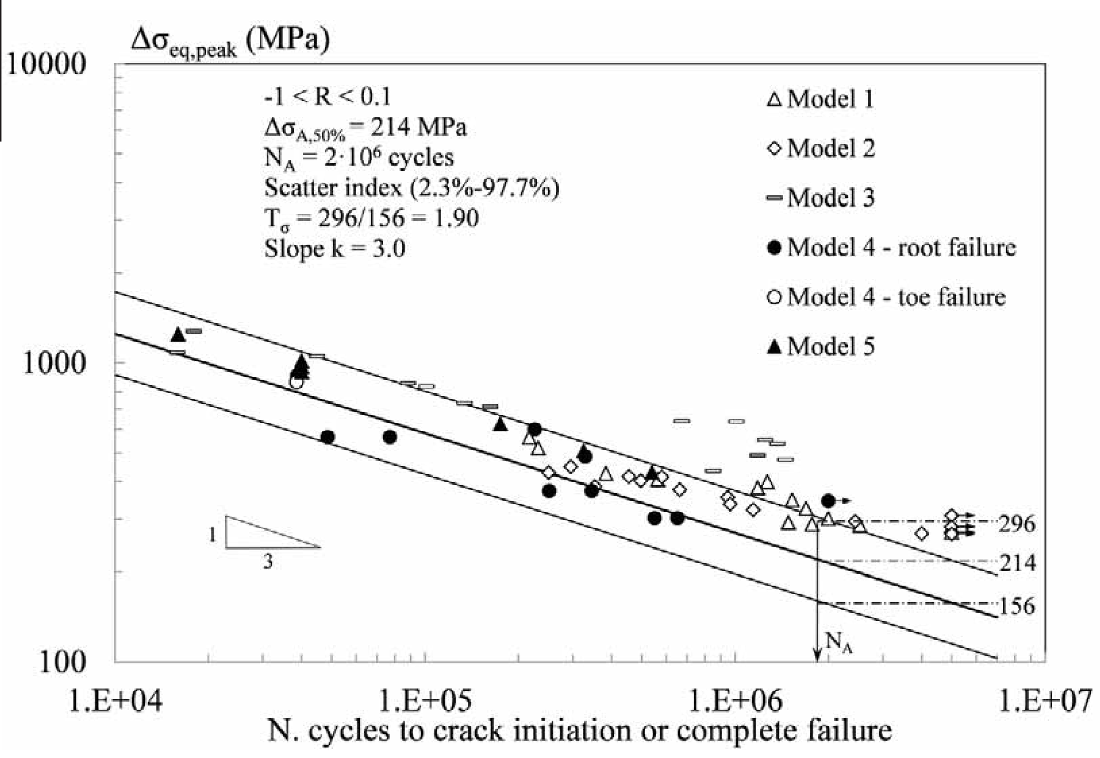


Table 1: Materials and fatigue test details.

Model	Material	Load ratio	Failure location	Failure criterion
Model 1,2	Grade A steel	-1	Weld toe	Complete failure
Model 3	AH32	-1	Weld toe	Complete failure
Model 4	S355	0.1	Weld toe/root	Complete failure
Model 5	S355	0.1	Weld toe	Dye penetrant insp.





Fatigue test results compared with the single design scatter band proposed by the Peak Stress Method.