



A research project was initiated at McGill University and Polytechnique Montréal by Moreau et al. [1], who conducted laboratory tests and FE modeling of two square HSS brace sizes (HSS 152×152×9.5 and HSS 203×203×13) to determine the minimum overlap length required to develop the yield resistance of the braces over their full length. This study led to the recommendation that an overlap length of 5% of the weld length in the SHG connection could be sufficient to develop the yield tensile resistance of the HSS brace. Overall design and detailing rules were not developed from these past research projects. Thus, the aforementioned research program was continued, with the objective of developing general design and detailing rules for the SHG HSS brace connection through a combination of laboratory testing and advanced numerical analysis. Described herein, is the preliminary phase of the numerical analysis, comprising a parametric study carried out using 3D continuum finite element (FE) models of the Slotted-Hidden-Gap connection for square HSS braces to evaluate the influence of different geometrical parameters on the overall performance.

2. Finite Element Simulations

2.1 Overview and Methodology

To better understand the different geometric properties that influence the behaviour of a SHG connection, a numerical parametric study was conducted. Monotonic tensile loading of the connection was investigated for this study because it represents an extreme loading case, and also gives an opportunity to study the stress-strain distribution of the connection before proceeding into the reversed-cyclic loading routine.

Table 1 - Summary of finite element model variables

HSS Size	HSS thickness (mm)	L _w (mm)	D _w (mm)	W _g (mm)	t _g (mm)	L _{wg} (mm)
Part 1 - HSS Parameters						
HSS 305x305	19	460	32	840	32	19
	16		29		29	
HSS 254x254	16	390	29	700	29	16
	13		25		25	
HSS 203x203	16	280	29	530	29	13
	13		25		25	
	9.5		19		22	
HSS152x152	16	210	29	390	29	10
	13		25		25	
	9.5		19		22	
	8		16		19	
Part 2 - Weld Parameters						
HSS 254x254	13	260	32	700	25	16
		390	25			
		620	19			
Part 3 - Gusset Plate Parameters						
HSS 254x254	13	390	25	700	19	16
					22	
					25	
					29	
					32	

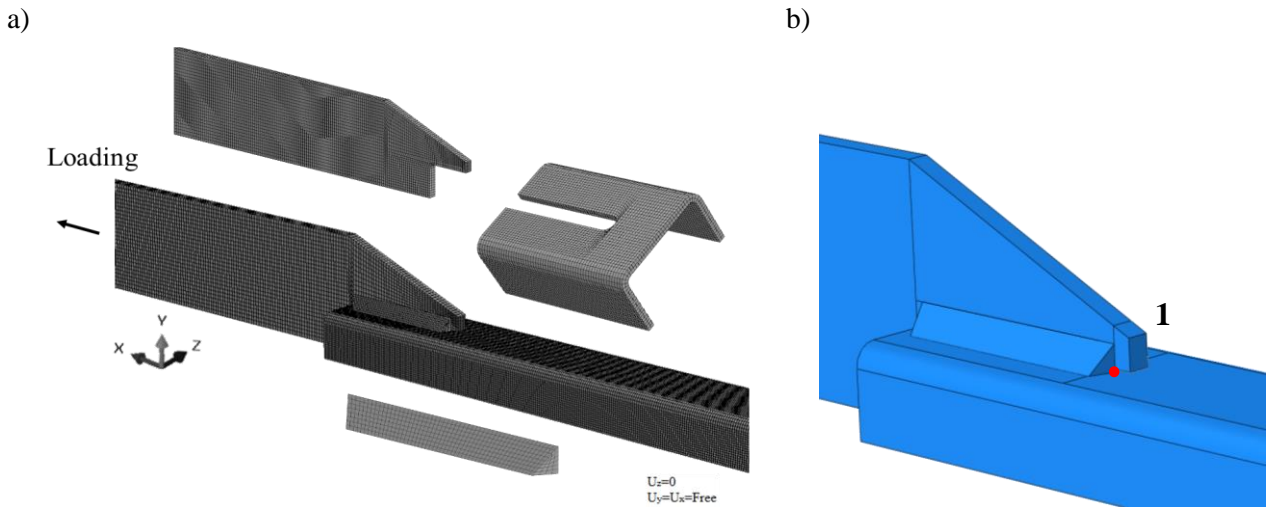


Fig. 4 – a) FE model showing model elements, mesh, boundary conditions and b) location 1 on the tube where axial strains were evaluated

3. Parametric Study Results

This section is divided into three main subsections to show the individual influence of the HSS parameters, the weld properties and the gusset plate dimensions on the performance of SHG connections under monotonic tension loading. A snapshot of prior FE analyses showing the difference in stress concentration between the conventional and SHG connection is displayed in Fig. 5. As shown, the SHG connection allows inelastic demands to develop along the tube and away from the connection region, compared to the conventional connection that concentrates inelastic demand in the net section region of the HSS brace.

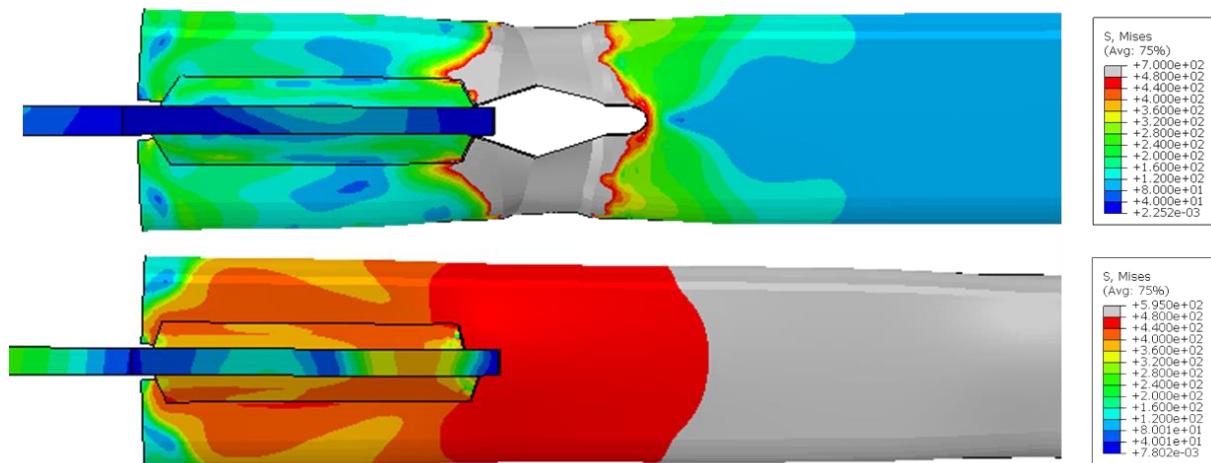


Fig. 5 – Snapshot of the connection region from the FE analysis of: Conventional connection (Top) and SHG connection (Bottom).

3.1 Influence of HSS Parameters (Part 1)

SHG connection demonstrates a PEEQ response of a steady increase until reaching a plateau, since the plastic strains concentrate at the brace mid-length, away from the connection, unlike the conventional connection where strains keep increasing until failure occurs in the connection region.

Values of the parameters varied are given in Table 1. The effect of varying the HSS size while keeping the same HSS wall thickness was first investigated. The local PEEQ-displacement response at



Contrarily, utilizing shorter welds of larger size (D_w) has revealed detrimental effects on the performance of SHG connections. It can be observed from Fig. 8 that the model with the short and large size weld ($L_w = 260$ mm, $D_w = 32$ mm) develops significantly higher inelastic demands at the connection region. Where the other models reach a PEEQ plateau at almost 60 mm of displacement (storey drift ratio = 6%), the model with the short weld length kept increasing, surpassing the PEEQ fracture limit of 0.8 [5] at only 90 mm of axial displacement (storey drift ratio = 9%).

Fig. 9 shows the variation of inelastic demands along the length of the HSS member for models with different weld parameters. The extreme cases of a long and small size weld, 620 mm length and 19 mm size, versus a short weld, 260 mm length and 32 mm size, were examined. The cross-section positions (A – I) along the HSS member, as denoted in Fig. 8, were chosen for evaluation for both cases. The bar and whisker graph shows the maximum, minimum, and average PEEQ values, as well as how far the values are dispersed from the mean at these cross-section locations. It is worth noting that the model with a short and large size weld Fig. 9a) has reached the highest PEEQ value of 1.0 at the connection region (Point D), whereas the long and small size weld model (Fig. 9b) has achieved the same PEEQ value at the mid-length of the HSS brace (Point I). The variability within each cross-section is displayed through the box length. The short weld model has displayed high variability of PEEQ values, especially at the connection region, mainly due to the presence of shear lag effects. For example, point D experienced a maximum PEEQ of 1.0, minimum of 0.66 and mean of 0.85. The model with a longer weld has displayed a smoother PEEQ trend through the HSS length, and the least variability within each cross-section, which illustrates the diminished shear lag effects and the smoother load transfer mechanism between elements of SHG HSS connection.

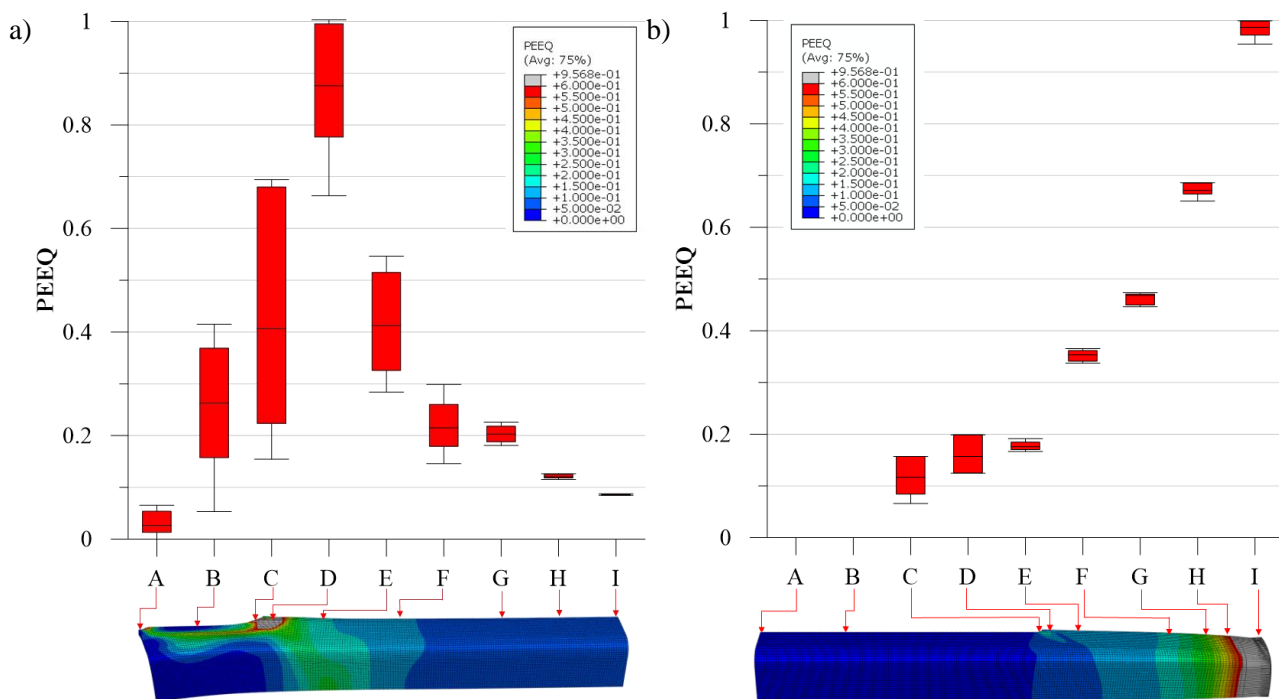


Fig. 9 – Variation of inelastic demands along HSS length for models with:
a) $L_w = 260$ mm - $D_w = 32$ mm, and b) $L_w = 620$ mm - $D_w = 19$ mm.

3.3 Influence of Gusset Plate Parameters (Part 3)

In this third part of the study the effect of the gusset plate thickness on the performance of the SHG connection was examined through modelling five different thicknesses of the gusset plate, from 19 mm to 32 mm, matching the common plate thicknesses found in North American practice. To independently investigate the effect of the gusset plate thickness on the SHG performance, five models of HSS 254x254x13 were examined while keeping the weld parameters, the gusset plate width and the weld overlap length unchanged.



5. Future Work

This numerical parametric study was limited to a few geometric aspects of SHG connections; more parameters are to be investigated in the future, including different material grades and various geometries of the connection and its components. A laboratory testing program is also planned, which will include additional SHG HSS configurations that have not previously been tested. The results of the laboratory study will be used in further calibration of the FE models. Design recommendations will ultimately be developed and verified through the evaluation of reversed-cyclic force / deformation loading on SHG HSS connections.

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7. References

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