5th International Experts Seminar:

Stainless Steel in Structures

Study on the static performance of stainless steel tubular T-joints

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Overview

- ✓ Introduction
- ✓ Experiments on T-joints
- ✓ FE simulations on T-joints
- ✓ Parametric analysis on T-joints
- ✓ Ultimate capacity formula of T-joints
- ✓ Conclusions

01 Introduction

✓ Tubular joints in circular hollow section

- Simple form
- Convenient construction
- Good performance
- Low cost

✓ Design of stainless steel tubular joints

- Based on carbon steel sections
- Lack of design rules

✓ Aims of study

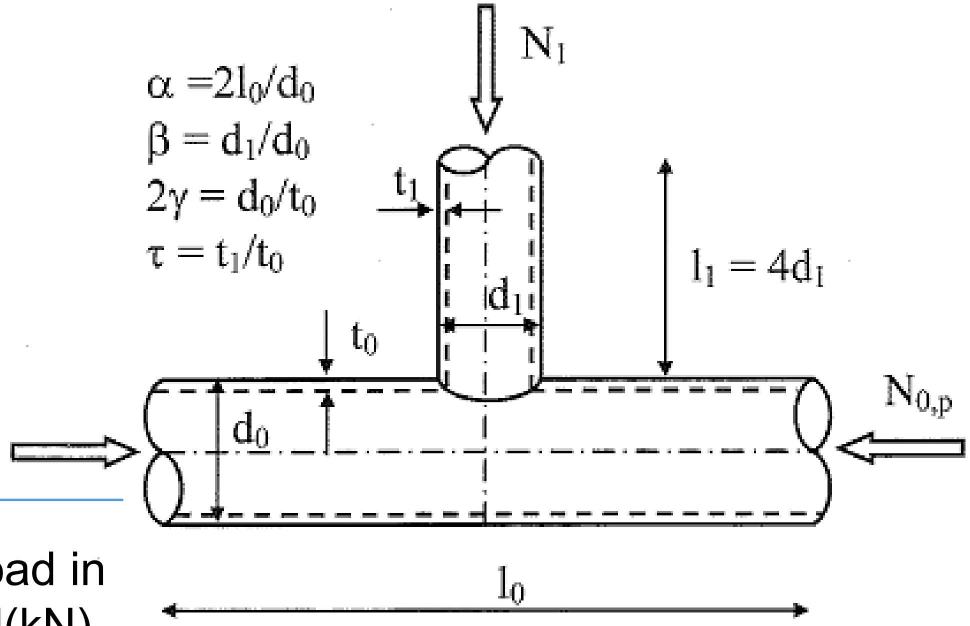
- Experimental and numerical investigations performed
- To propose the ultimate strength design formula

02 Experiments on T-joints

✓ Content of experiment

- Material tensile coupon tests
- Static force loading tests

Specimen no.	Chord (mm)		Brace (mm)		t_w (mm)	Preload in chord(kN)
	d_0	t_0	d_1	t_1		
TC102×76a	102	3.0	76	2.0	3.0	0.00
TC102×76b	102	3.0	76	2.0	3.0	-50.00
TC102×76c	102	3.0	76	2.0	3.0	-100.00
TC102×76d	102	3.0	76	2.0	3.0	-150.00
TC102×76e	102	3.0	76	2.0	3.0	100.00
TC102×89	102	3.0	89	2.5	3.5	0.00



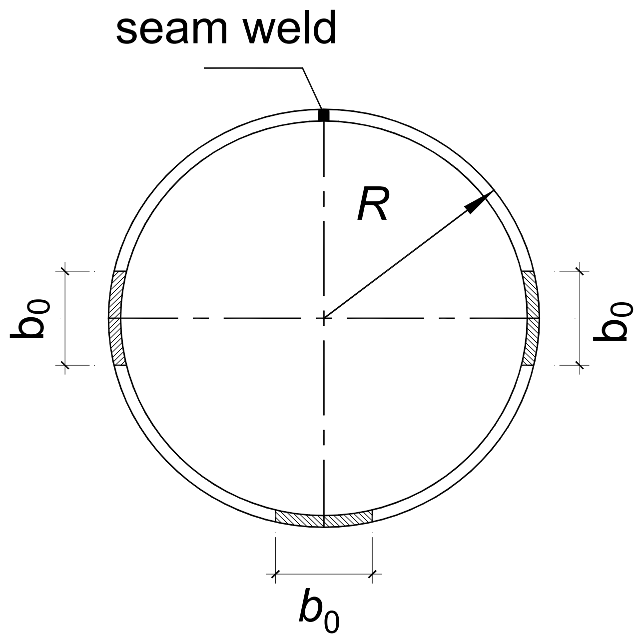
TC102×76b

02 Experiments on T-joints

✓ Material properties

- S30408 (0Cr18Ni9)

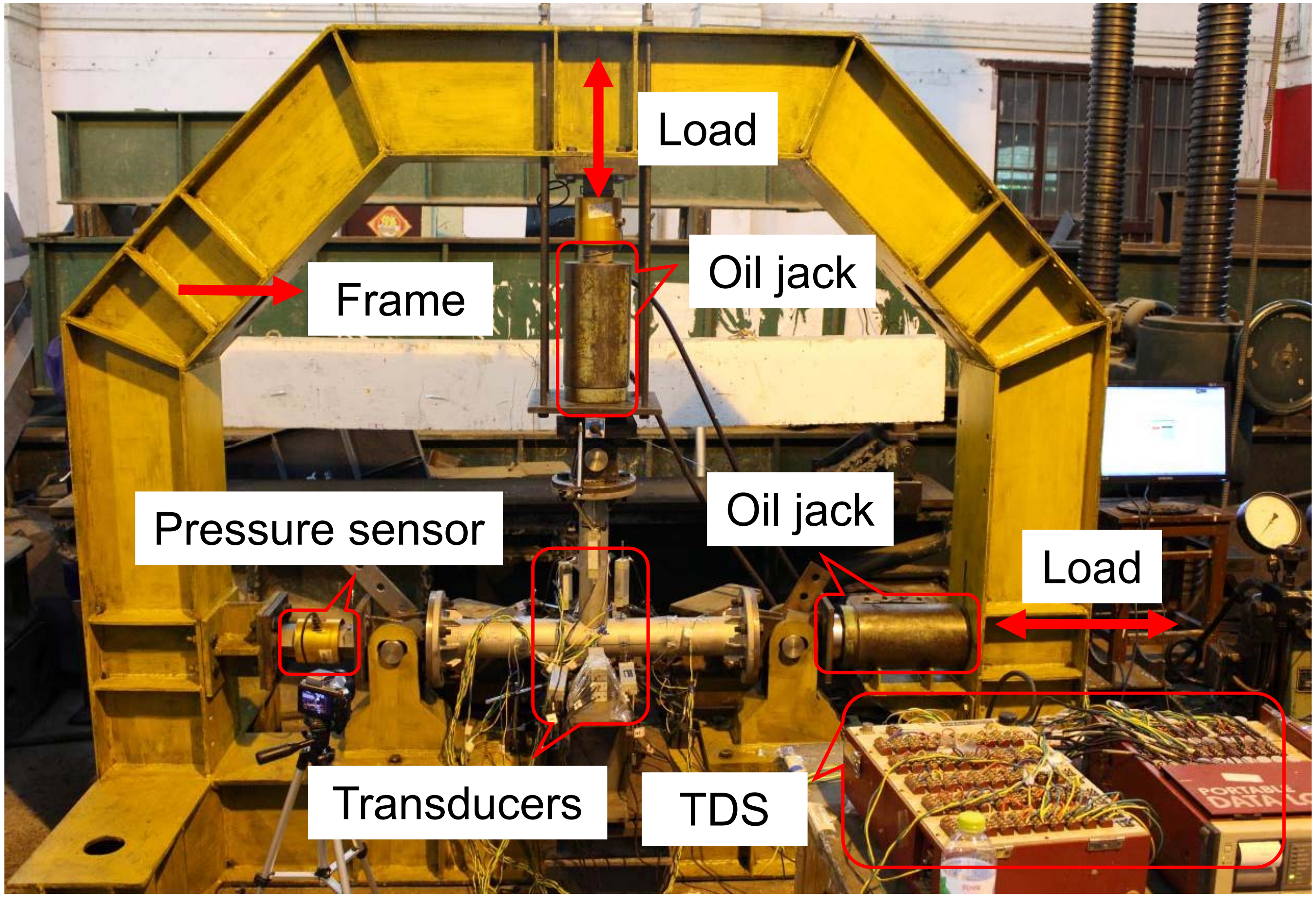
Test series	E_0 (Mpa)	$\sigma_{0.2}$ (Mpa)	n	σ_u (Mpa)
Φ76	193583	338	6.1	725
Φ89	189053	388	4.0	806
Φ102	203670	387	5.8	767



- Accurately described by Gardner-Nethercot model

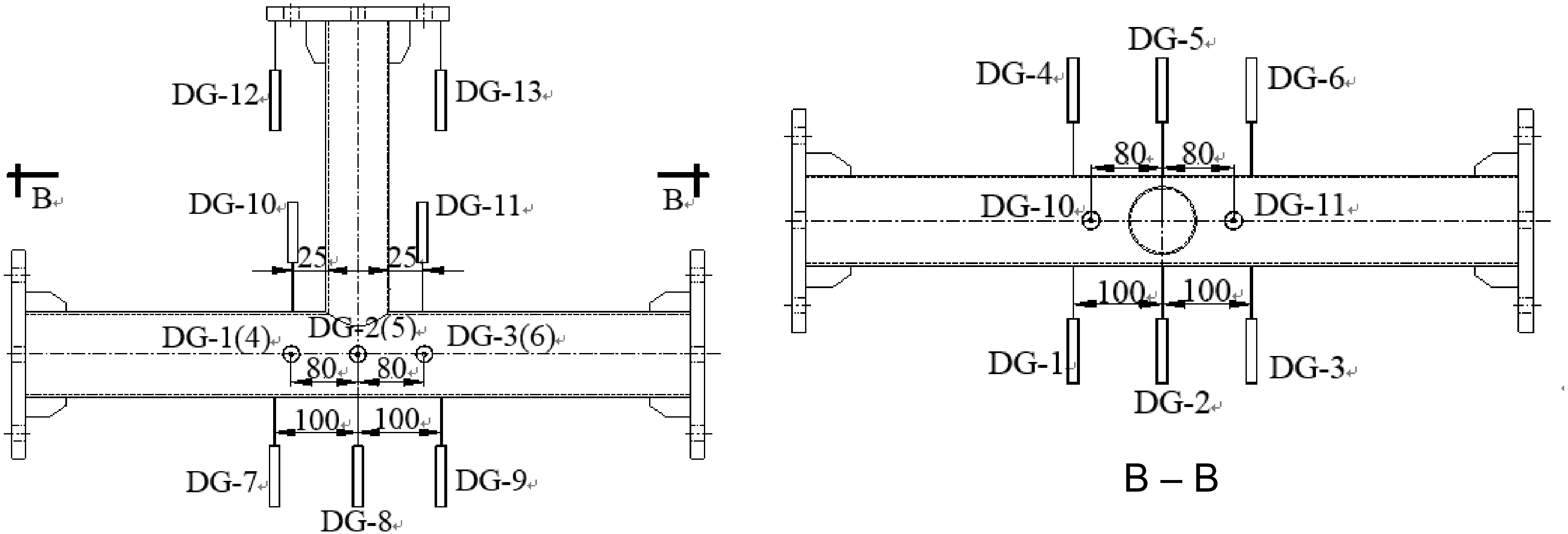
02 Experiments on T-joints

✓ Test rig



02 Experiments on T-joints

✓ Arrangement of displacement transducers



- DG1~DG6: to measure the outward deflections of chord side wall
- DG7~DG9: to measure the vertical flexural deflections of chord
- DG10~DG11: to measure the vertical deflections of connecting face of the chord
- DG 12~DG13: to measure the axial shortening of the brace

02 Experiments on T-joints

✓ Test results – joint failure mode

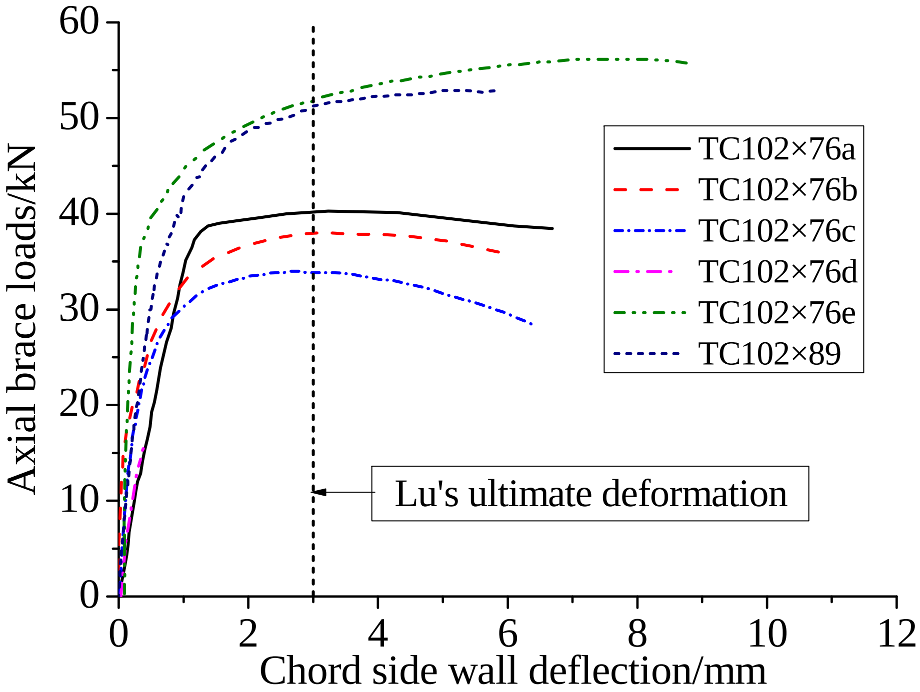
Chord side wall failure

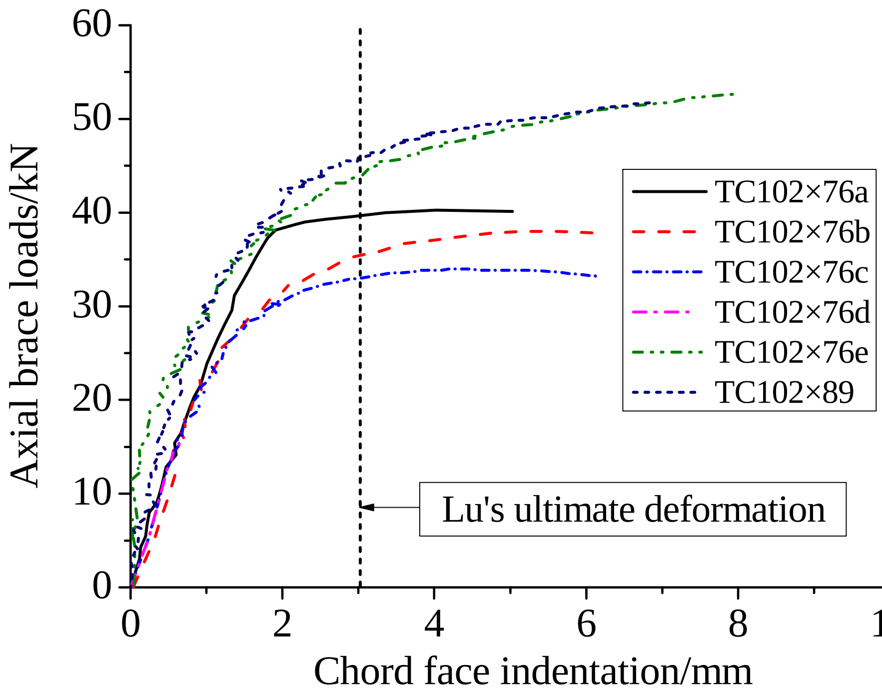
Chord face failure

- Chord side wall outward in the regional joints
- Chord face squeezed into an oval

02 Experiments on T-joints

✓ Test results – load deformation curves





- Curves with a clear peak load (TC102×76a~d)
- Curves without a clear peak load (TC102×76d~e, TC102×89)
- Adopt Lu's deformation limit to determine the failure load

02 Experiments on T-joints

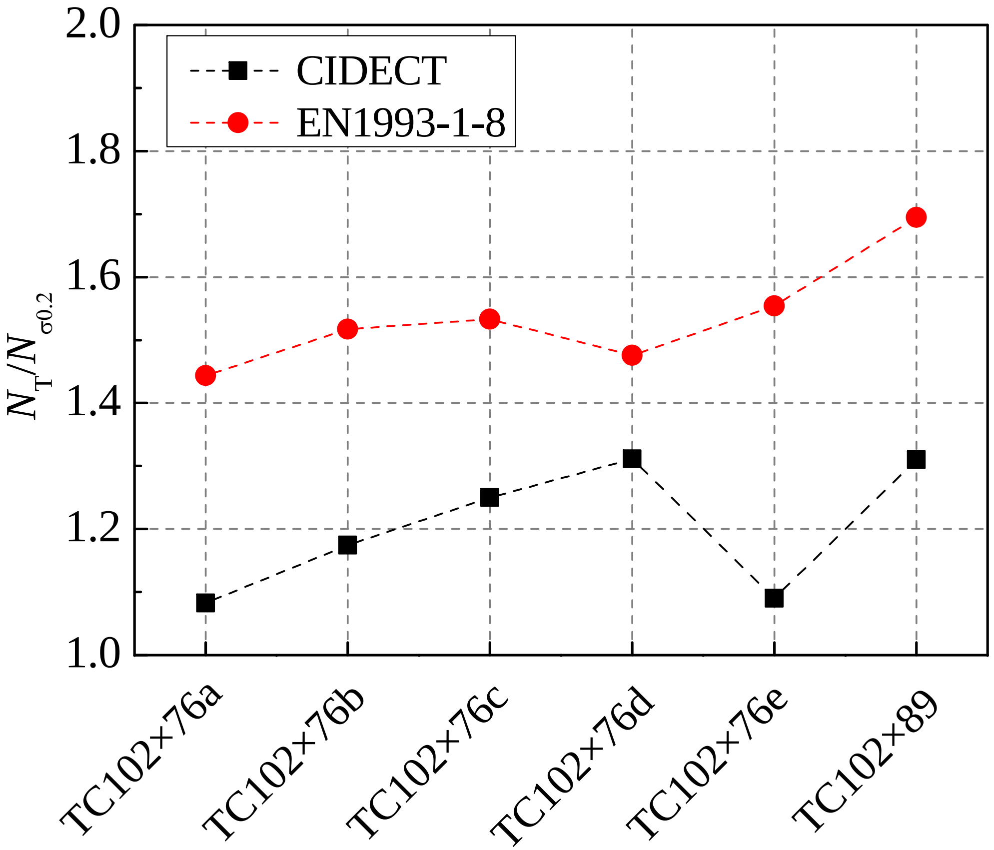
✓ Test results – joint failure load

Specimen no.	Peak load (kN)	Failure load(kN)	Preload in chord (kN)	Failure mode
TC102×76a	40.29	40.29	0.00	Chord plastic failure
TC102×76b	38.00	38.00	-50.00	Chord plastic failure
TC102×76c	34.00	34.00	-100.00	Chord plastic failure
TC102×76d	28.43	28.43	-150.00	Chord plastic failure
TC102×76e	56.14	52.00	100.00	Chord plastic failure
TC102×89	52.86	51.29	0.00	Chord plastic failure

- The compressive chord preload increased, the joints failure load decreased
- The tensile chord preload significantly strengthened the T-joints

02 Experiments on T-joints

✓ Comparison of test results and code results

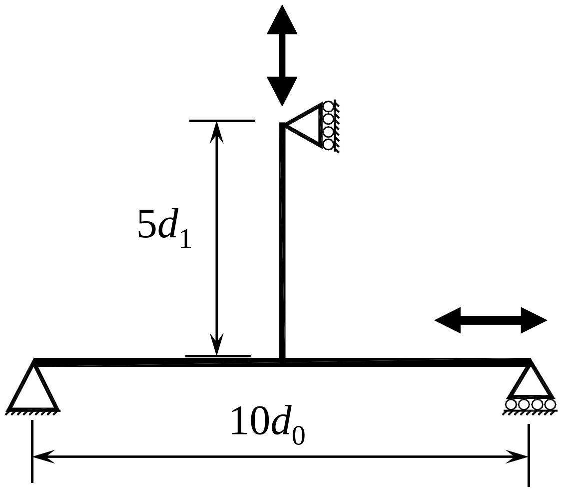


- $f_y \longrightarrow \sigma_{0.2}$
- $N_{\sigma0.2}$: design strength of codes
- N_T : design strength of tests
- The tested-to-predicted design strength ratios larger than 1
- Conservative predictions of codes

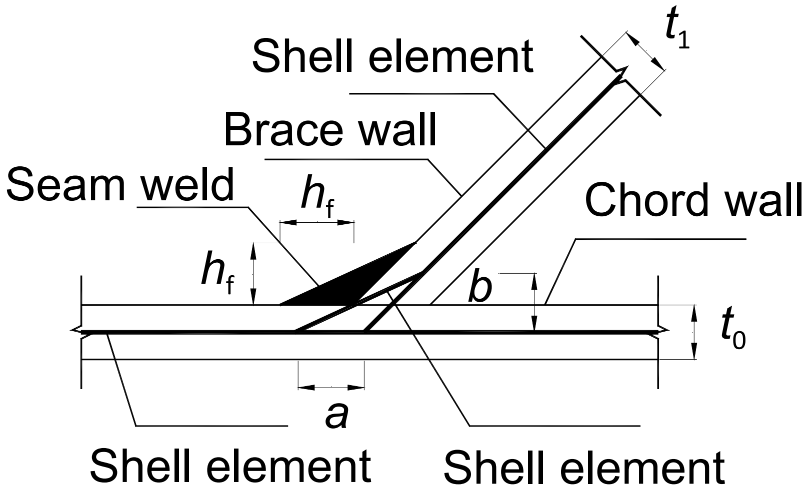
03 FE simulation on T-joints

✓ ANSYS

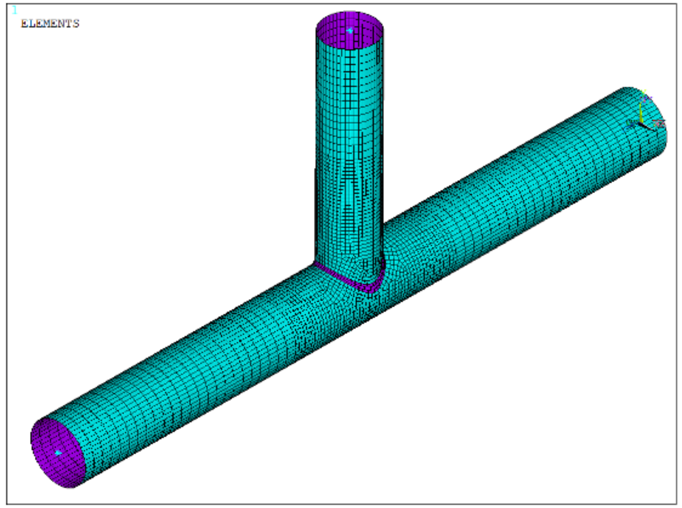
- Element: SHELL 181



Physical dimension



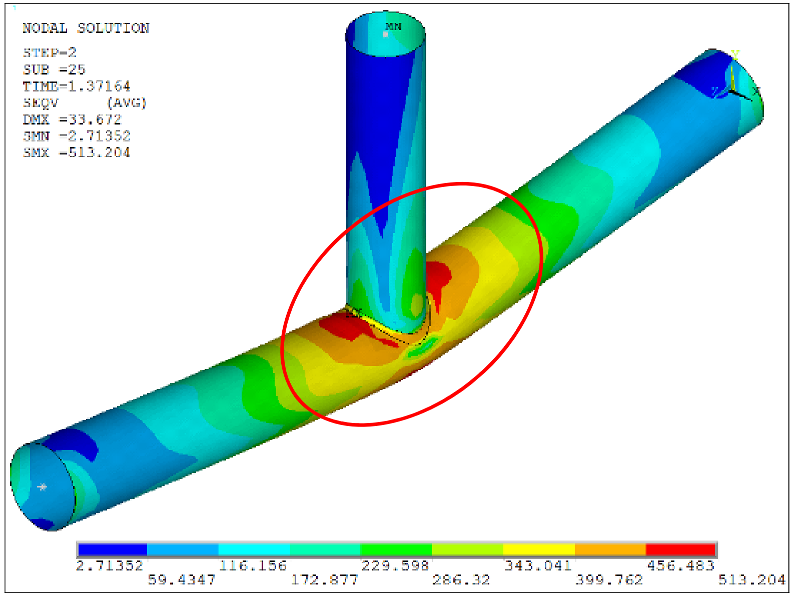
Seam weld

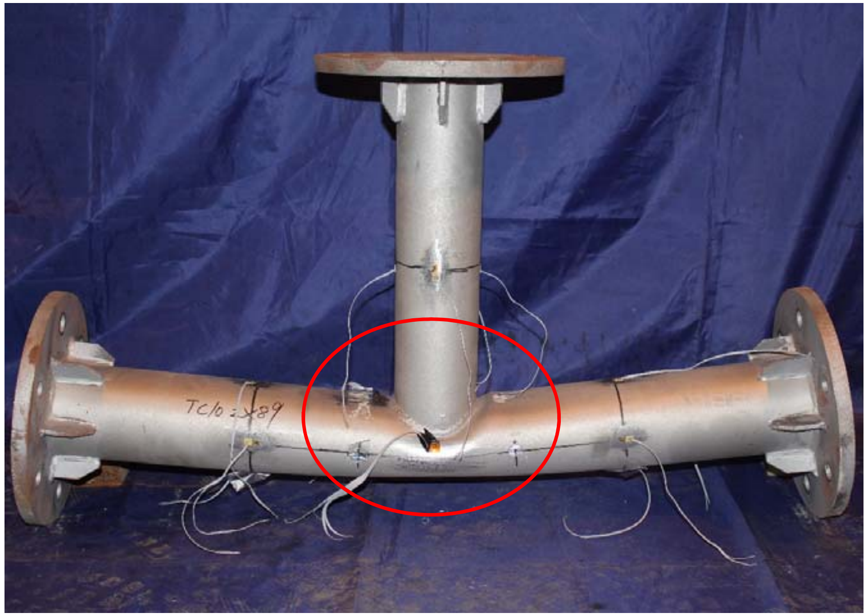


Model meshing

03 FE simulation on T-joints

✓ FE results – joint failure mode





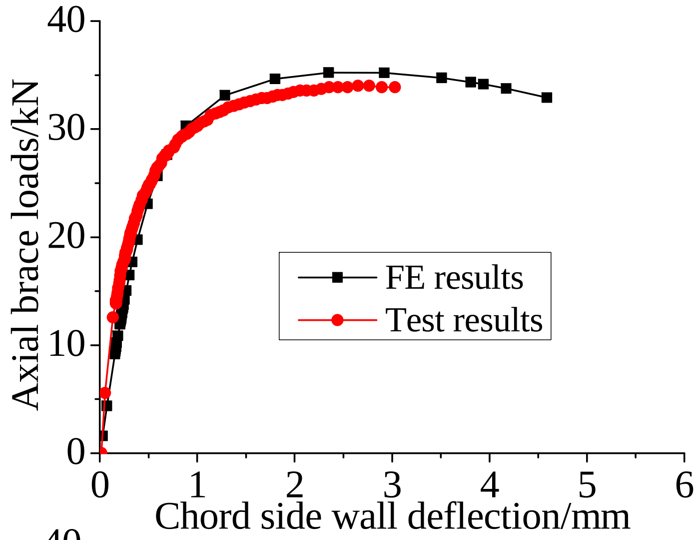
- The local joint failure mode of FE simulations was same as that of tests

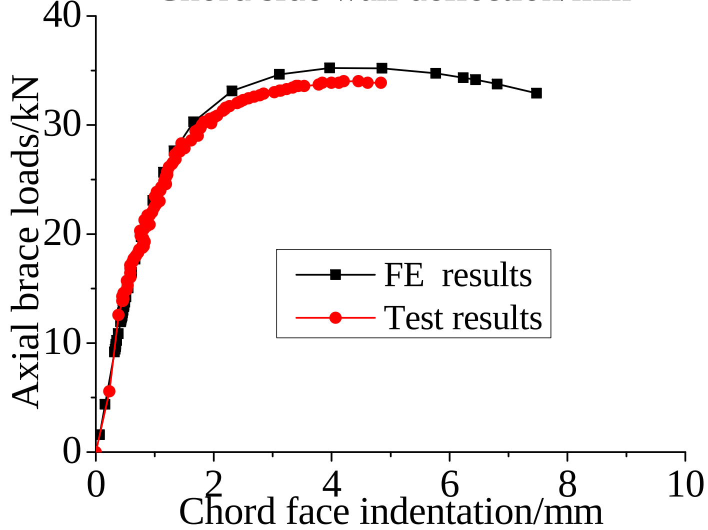
03 FE simulation on T-joints

✓ Comparison of test results and FE results

Specimen no.	N_T(kN)	N_F(kN)	N_F/N_T
TC102×76a	40.29	42.97	1.07
TC102×76b	38.00	38.40	1.01
TC102×76c	34.00	35.22	1.04
TC102×76d	28.43	28.54	1.00
TC102×76e	52.00	49.01	0.94
TC102×89	51.29	48.94	0.95

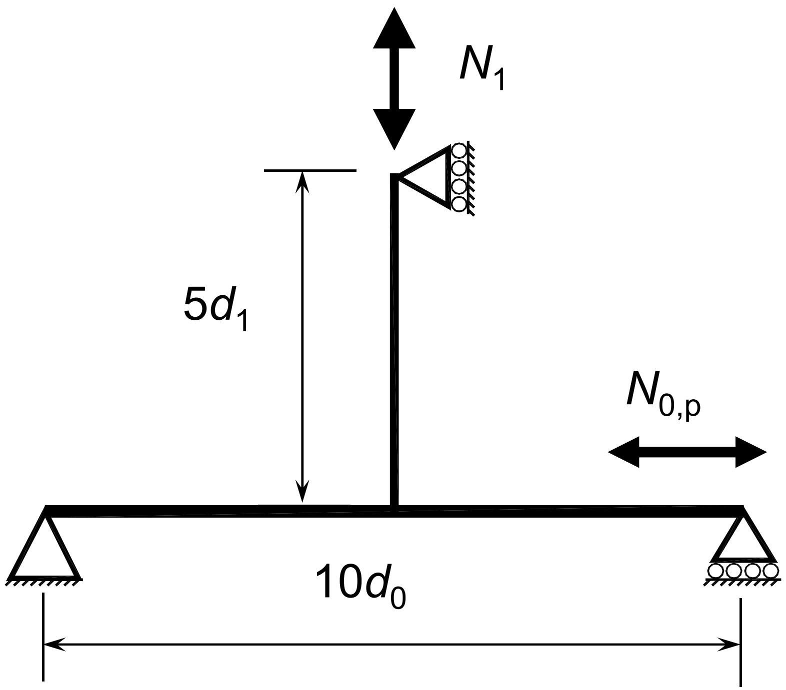
- N_T: ultimate strength of tests
- N_F: ultimate strength of FE
- The test results and FE results fitted well





04 Parametric analysis on T-joints

✓ Physical parameters



d_0=200mm

d_1=50, 100, 150, 180mm

t_0=8.0, 6.0, 4.5, 3.2mm

β=0.25~0.90

2γ=25.00, 33.33, 44.44, 62.50

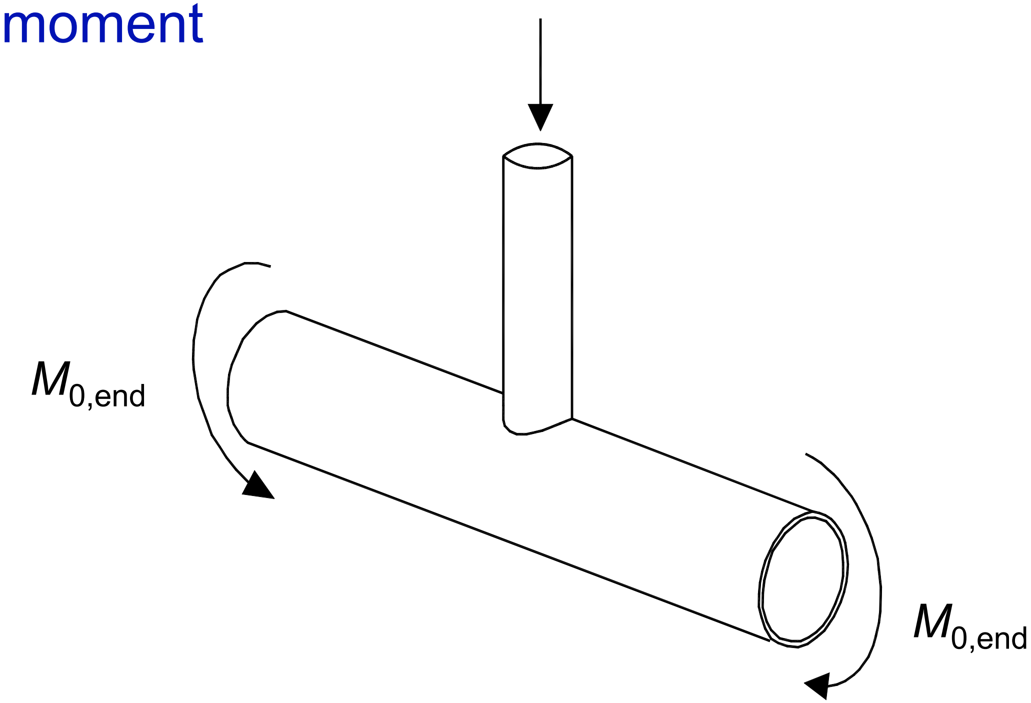
$N_{0,p}/A_0\sigma_{0.2}$

↓

Q_u Q_f

04 Parametric analysis on T-joints

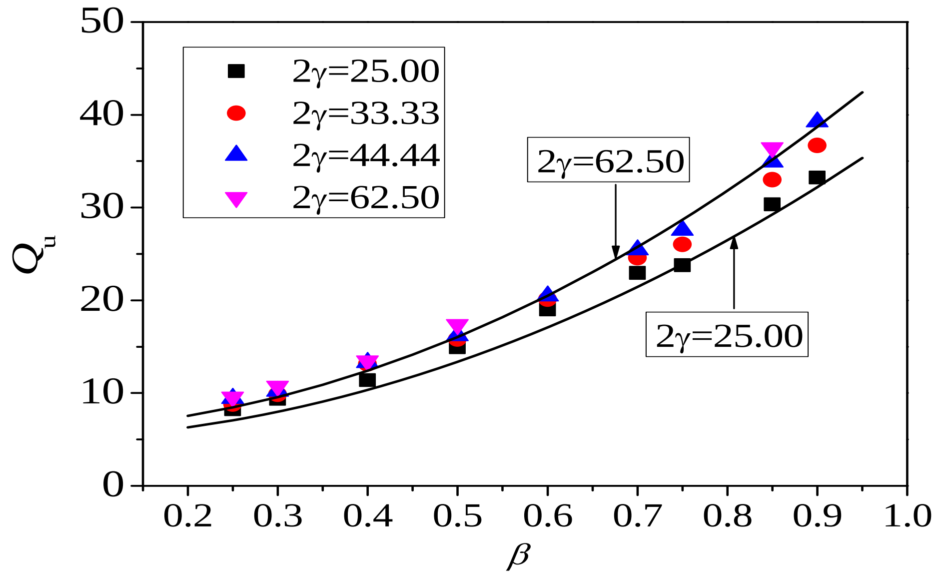
✓ Compensating moment



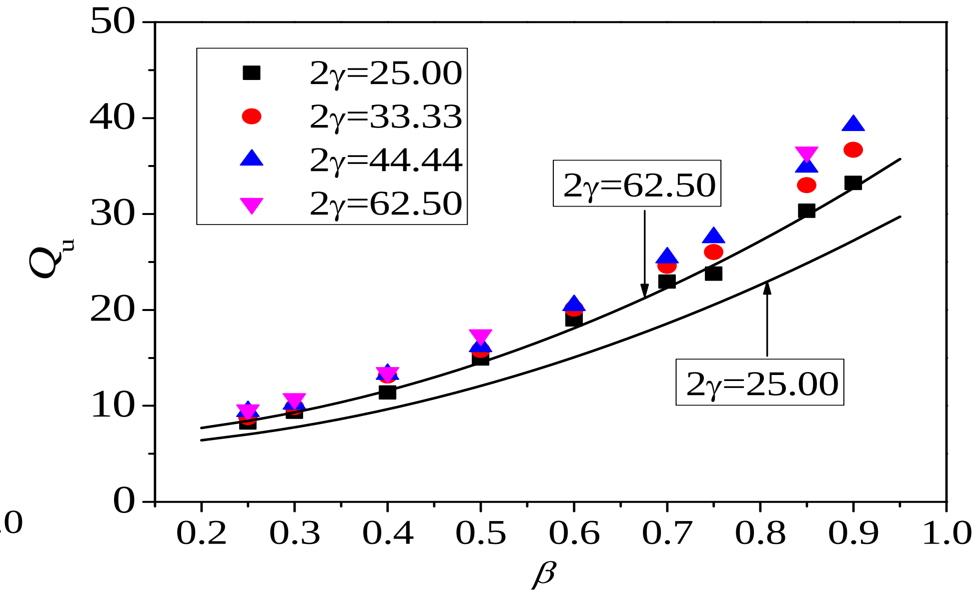
- Chord in-plane bending unavoidably caused by axial brace loads
- Exclude the chord bending effect to derive the local strength

04 Parametric analysis on T-joints

✓ Geometric function – Q_u



FE vs CIDECT



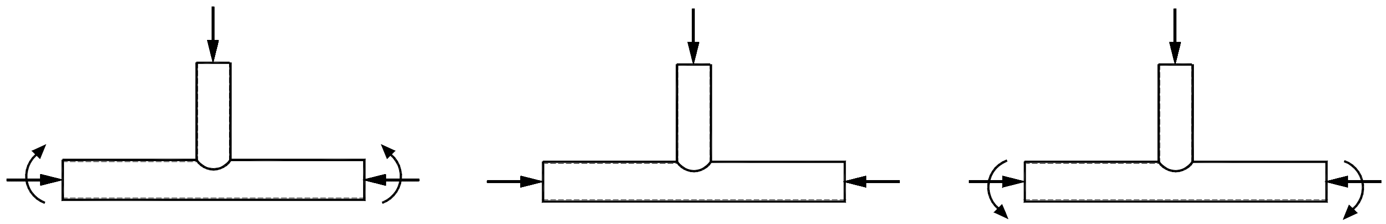
FE vs EN1993-1-8

- *β* increased, Qu increased and 2*γ* increased, Qu decreased
- Little difference of Qu between FE results and CIDECT predictions

04 Parametric analysis on T-joints

✓ Chord stress function– Q_f

- Combination of different parameters



<table>
<tr><td rowspan="3">β=0.25, 0.50, 0.75, 0.90</td><td>$M_{0,p}/M_{pl,0}$=-0.2,-0.4</td><td>$M_{0,p}/M_{pl,0}$=0.0</td><td>$M_{0,p}/M_{pl,0}$=0.2,0.4</td></tr>
<tr><td colspan="3">$N_{0,p}/A_0\sigma_{0.2}$=-0.2,-0.4</td></tr>
<tr><td colspan="3">2γ=25.00、33.33、44.44、62.50</td></tr>
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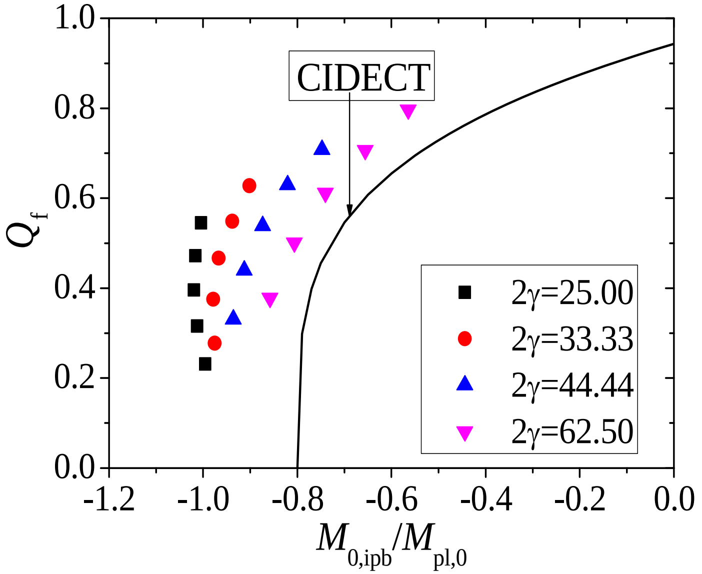
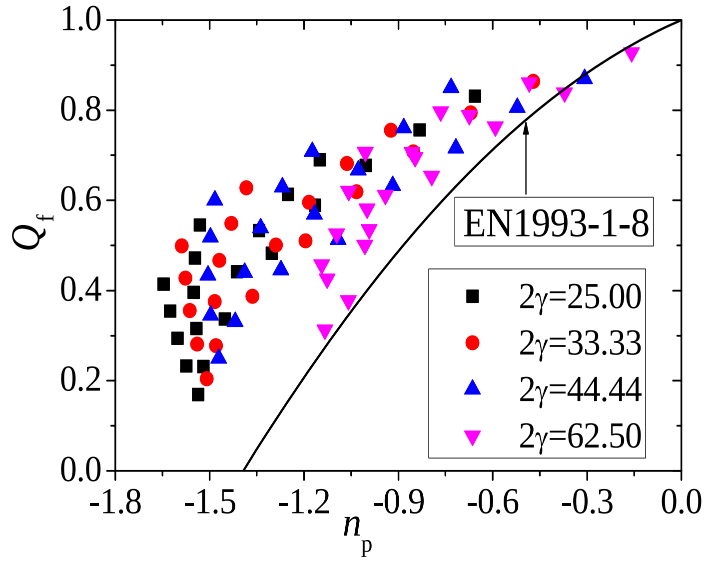
04 Parametric analysis on T-joints

✓ Chord stress function– Q_f



FE vs CIDECT



FE vs EN1993-1-8

- The value of Q_f calculated by related codes imprecise and conservative compared to FE results.

05 Ultimate strength formula of T-joints

✓ The proposed formula

$$N_u = \frac{\sigma_{0.2} t_0^2}{sin\theta} Q_u Q_f$$

$$Q_u = 3.68(1 + 5.60\beta^2)\gamma^{0.2}$$

$Q_u \rightarrow$ refer to CIDECT

$$Q_f = 1 + 0.15n_{pl} - 0.55n_{pl}^2, n_{pl} < 0$$

$$Q_f = 1.0, n_{pl} \geq 0$$

$Q_f \rightarrow$ refer to EN1993-1-8

$$n_{pl} = \frac{N_{0,p}}{N_{pl,0}} + \frac{M_{0,ipb}}{M_{pl,0}}$$

05 Ultimate strength formula of T-joints

✓ Comparison of test results and predictions

Specimen no.	N_T(kN)	N_M(kN)	N_T/N_M
TC102×76a	40.29	39.18	1.0283
TC102×76b	38.00	34.92	1.0881
TC102×76c	34.00	30.60	1.1112
TC102×76d	28.43	26.16	1.0868
TC102×76e	52.00	47.41	1.0969
TC102×89	51.29	41.66	1.2311
AVG.			1.1071
SD.			0.0670

- N_T : ultimate strength of tests
- N_M : ultimate strength of proposed formula
- Predictions of proposed formula accurate and safe relatively

06 Conclusion

a) The local joint failure modes involved chord side wall failure and chord face failure.

b) The test results were compared with the design predictions obtained from the CIDECT, EN1993-1-8 for carbon steel. It is shown that the design predicted strength are conservative for the test specimens calculated using the 0.2% proof strength as the yield strength.

c) The numerical simulations and parametric analysis were carried out on 230 T-joints. The ultimate strength formula of T-joints were proposed. Compared to the test results, the predictions had good accuracy and reliability.

Thanks for your attention!

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