DEEP LEARNING SOLUTION FOR STRENGTH PREDICTION OF STEEL CHS X-JOINTS

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INTRODUCTION

- Steel CHS (Circular Hollow Section) X-Joints:

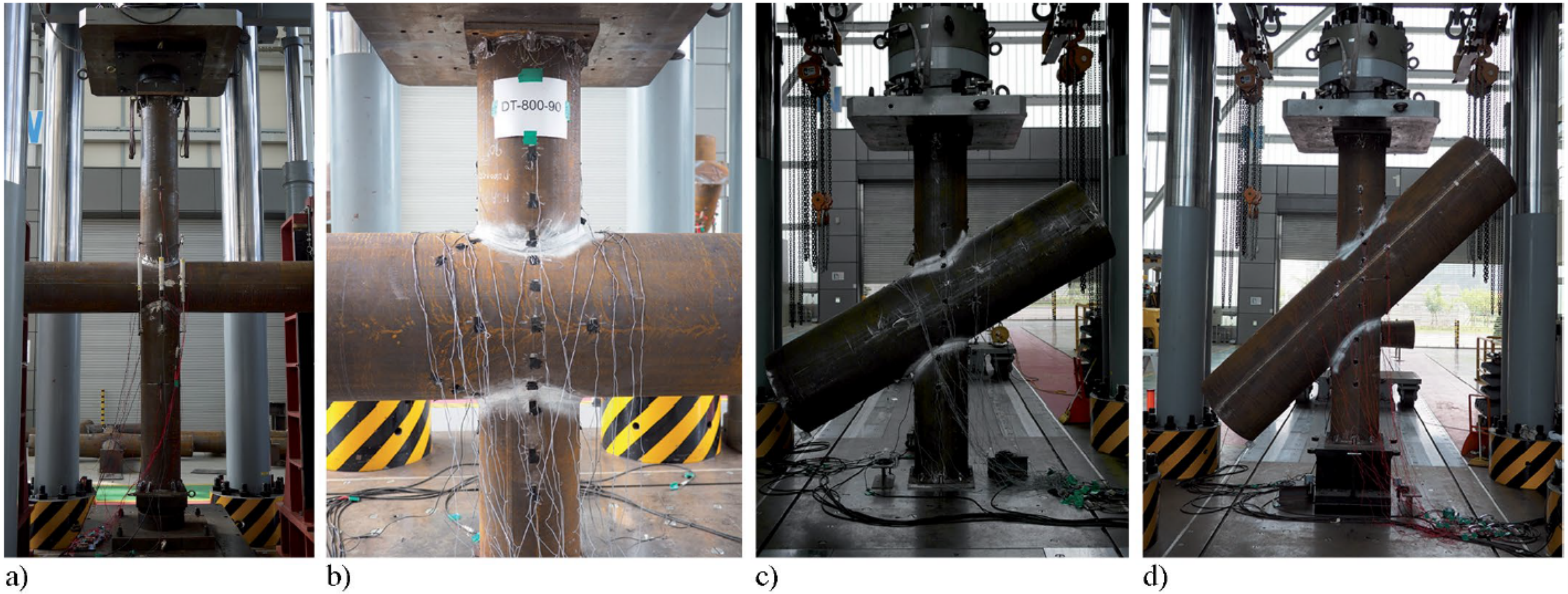
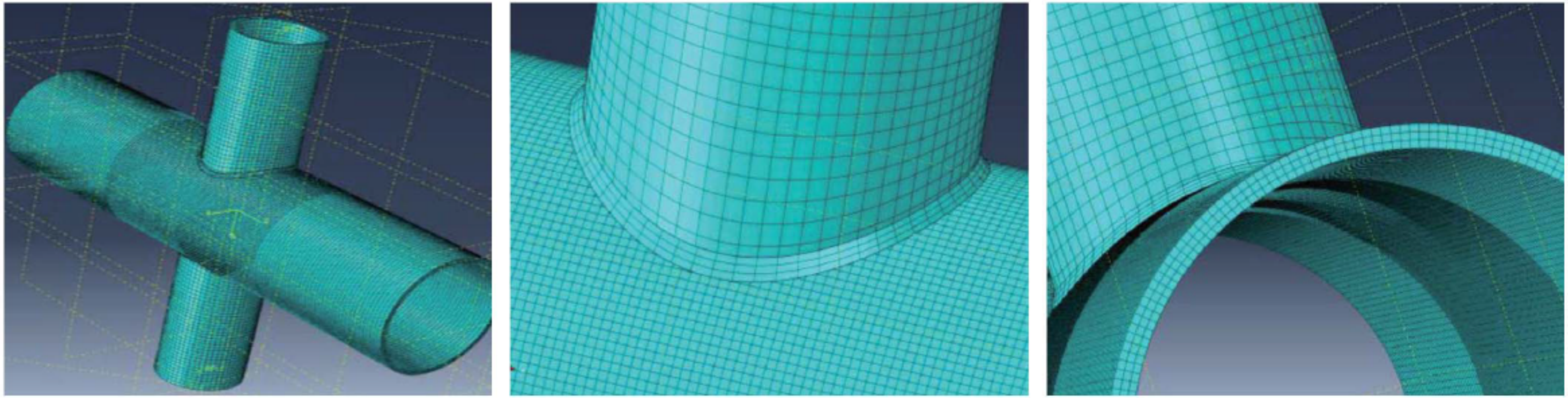


Fig. 2. HSA800 test specimens: a) $\beta = 0.75$, $\theta = 90°$, b) $\beta = 0.62$, $\theta = 90°$, c) $\beta = 0.62$, $\theta = 60°$, d) $\beta = 0.62$, $\theta = 45°$

INTRODUCTION

- Strength prediction by Numerical Finite Element (FE) model:



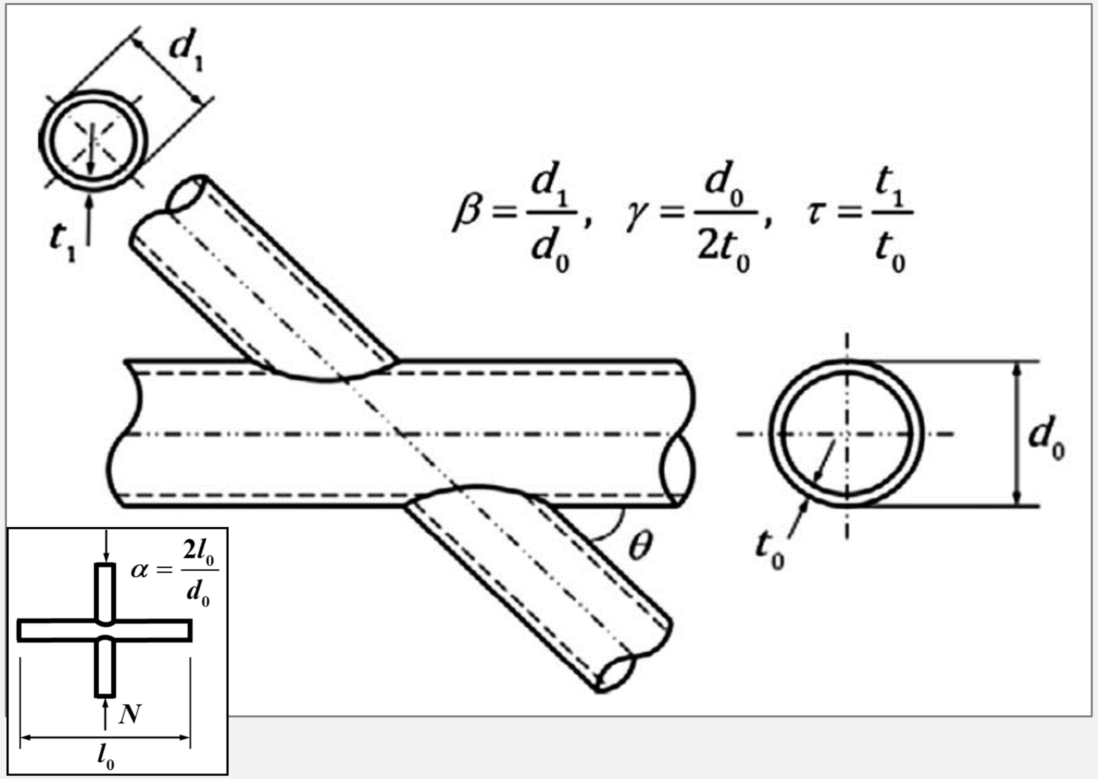
(a) (b) (c)

Fig. 7. Typical FE analysis meshes: (a) overall view; (b) weldment modeling; (c) meshes through thickness

Problem: FE analysis requires high computational resources

DATA DESCRIPTION

- CHS X-joint configuration:



- Learning features (Input parameters):

1. Chord Diameter d_0 (mm)
2. Yield Stress (Fy)
3. Ultimate Stress (Fu)
4. Beta (brace-to-chord diameter ratio)
5. 2-Gamma (chord thickness-to-diameter ratio)
6. CSL (chord stress level)
7. Tau (brace-to-chord thickness ratio)
8. Alpha (chord radius-to-length ratio)

- Prediction (Output):

Strength (ksi)

DATA DESCRIPTION

- Learning examples from FE model:

Diameter	Fy (MPa)	Fu (MPa)	Beta	2-Gamma	CSL	Tau	Alpha	Ultimate strength (kN)
474.2	382	563	0.77204	44.526	0	0.8779	11.388	739.18993
101.6	318	437	0.47835	34.209	0	0.7744	3.937	20.8719
101.6	318	437	0.47835	34.209	0	0.7744	5.9055	28.3136
101.6	318	437	0.47835	34.209	0	0.7744	7.874	31.059928
101.6	318	437	0.47835	34.209	0	0.7744	9.8425	31.516691
101.6	318	437	0.47835	34.209	0	0.7744	11.811	32.338692
101.6	318	437	0.47835	34.209	0	0.7744	15.748	34.067082
101.6	318	437	0.47835	34.209	0	0.7744	19.685	34.872545
101.6	318	437	0.47835	34.209	0	0.7744	23.622	35.047904
101.6	400	462	0.21358	32.152	0	0.7278	15.748	27.87627

Total 3710 simulation results with different configurations of X-joint for model learning

- Testing data from physical model:

Diameter	Fy (MPa)	Fu (MPa)	Beta	2-Gamma	CSL	Tau	Alpha	Ultimate strength (kN)
400	324	518	0.75	16	0	0.6	15	3725
650	324	518	0.615	26	0	1	7.7	2640
650	478	586	0.615	26	0	1	7.7	3759
650	798	914	0.615	26	0	1	7.7	5612

4 experimental data for testing

IMPLEMENTATION & RESULT

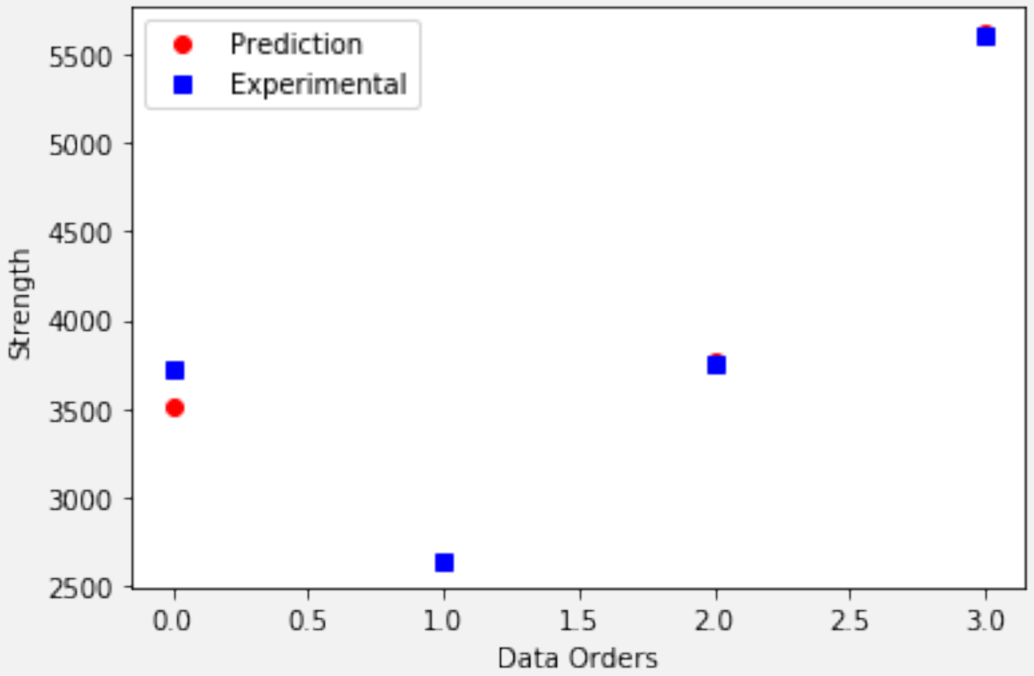
- Deep Learning Numerical Regression
- Input Normalization
- 10% as validation set
- Network structure

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
flatten_2 (Flatten)          (None, 8)                 0
_________________________________________________________________
dense_8 (Dense)              (None, 128)               1152
_________________________________________________________________
dense_9 (Dense)              (None, 64)                8256
_________________________________________________________________
dense_10 (Dense)             (None, 64)                4160
_________________________________________________________________
dense_11 (Dense)             (None, 1)                 65
=================================================================
Total params: 13,633
Trainable params: 13,633
Non-trainable params: 0
```

```
model.compile(optimizer='Nadam',loss='mean_squared_error',metrics=['accuracy'])
```

```
hist = model.fit(x_train, y_train,epochs=500, batch_size=64, validation_split=0.1,verbose = 1)
```

IMPLEMENTATION & RESULT



Diameter	Fy (MPa)	Fu (MPa)	Beta	2-Gamma	CSL	Tau	Alpha	Ultimate strength (kN)
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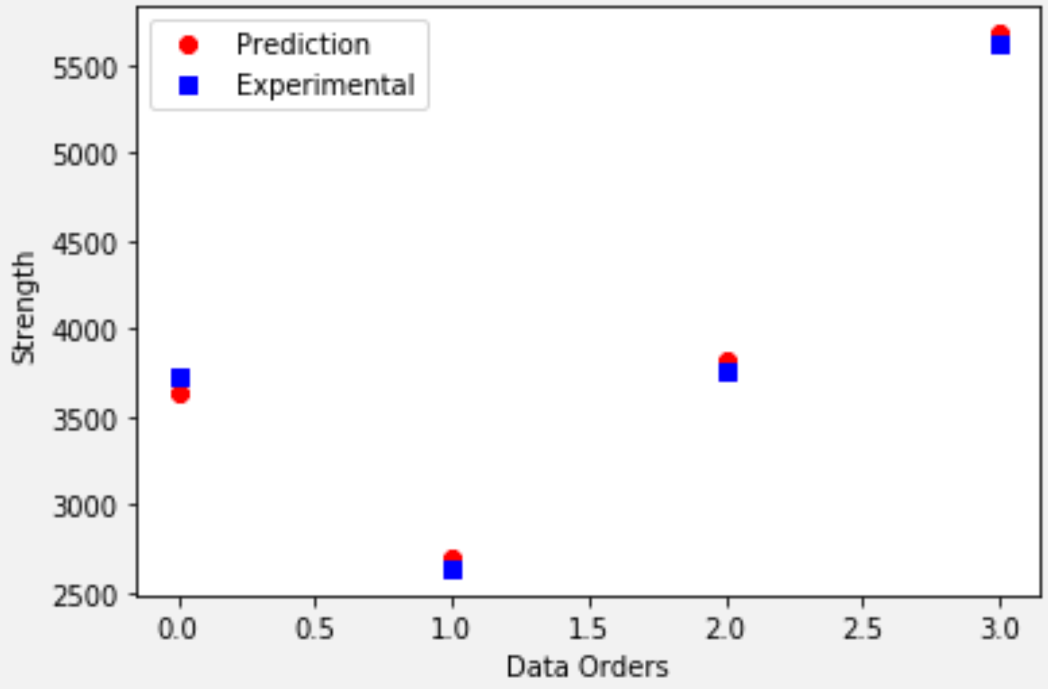
Notice that the first prediction data has some discrepancy.

IMPLEMENTATION & RESULT

Increase iteration:

```
hist = model.fit(x_train, y_train,epochs=1000, batch_size=100, validation_split=0.1,verbose = 0)
```



FUTURE WORK

- Utilize transfer learning to improve the model performance

REFERENCE

- Lee, Cheol-Ho, Kim, Seon-Hu, Chung, Dong-Hyun, Kim, Dae-Kyung, and Kim, Jin-Won. "Experimental and Numerical Study of Cold-Formed High-Strength Steel CHS X-Joints." *Journal of Structural Engineering* 143, no. 8 (August 1, 2017).
- Lee, Cheol-Ho, and Kim, Seon-Hu. "Structural Performance of CHS X-joints Fabricated from High-strength Steel." *Steel Construction* 11, no. 4 (November 2018): 278–285.