International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

Behavior of Ring Flange – Bolts Joint under Complex Bearing Forces

Le Anh Tuan

***Abstract:** With many advantages, nowadays, the structure using tubular steel structure is more and more widely used in all kinds of construction. In response to the rapid development of the tubular steel structure, it has been had a lot of research about the ring flange – bolts joints of this structure. Welding joints and ring flange – bolts joint are used most popular in tubular structure. However the joints using flanges and bolts are only mentioned in the case of simple load bearing such as tension or compression or bending without computational instructions in the case of complex bearing forces (concurrent shear force and bending or concurrent tension/compression and bending or tension/compression and twisting). The study outlines the behavioral rules for joints of tubular structure using ring flange – bolts joint in the case of concurrent shear force and bending, thereby proposing the rational parameters of the joint (the relationship between the thickness of the flange, the diameter of the bolt and thickness of steel tubes).*

***Keywords:** tubular steel; flanges; high strength bolt; concurrent shear force and bending; collapse mechanism.*

I. INTRODUCTION

A. Background

Tubular steel joint using flanges and bolts in truss structure are researched for a long time ago but the behaviors have just considered in very simple case considering the tension / compression stress separately. Actually, the joint like that have been affected in complex condition like concurrent of shear force, bending and axial force due to collapse mechanism.

B. Purpose

-Simulating the behavior of this joint under concurrent shear force, bending and axial force using FEM analysis.

- Evaluating the results and propose some suitable ratio in dimensions for flange(t_F) and bolt.

C. Research object and scope

- Tubular steel joint using flanges and bolt.
- Concurent shear force and bending

D. Research contents

- Simulating the joint of one bolt with apart of ring flange – bolt joint (L flange joint) .

- Evaluating the response of tubular steel jont under the concurrent of shear force and bending.

Revised Manuscript Received on October 30, 2019.
* Correspondence Author
Le Anh Tuan*, The University of Da Nang – University of Science and Technology , Danang city, Viet Nam. Email: latuan@dut.udn.vn

II. PROCEDURE FOR RESEARCH AND RESULTS

A. Basic Theory for Behavior of ring flange- bolt joint

1. *Schmidt – Neuper formula*: In case of concurrent of shear force and bending appear on the tubular steel joint, each bolt is necessary to determine tension acting on the bolt when performing the evaluation of fatigue damage of the bolt. Because when evaluating cumulative fatigue damage, fatigue limit curve has been used in Schmidt - Neuper diagram [5] (Fig.1), axial forces actually occur inside of the bolts are necessary to be determined . The axial force of one bolt cab be determined Schmidt - Neuper's evaluation formula (S-N formula)[2]. Fig.2 show the diagram of ring flange - bolt joint that considered in this research.

$$T_p = \begin{cases} T_v + pT_s & T_s \le T_{sI} \\ T_v + pT_{sI} + (\lambda T_{sII} - T_v - pT_{sI})\dfrac{T_s - T_{sI}}{T_{sII} - T_{sI}} & T_{sI} < T_s < T_{sII} \\ \lambda T_s & T_{sII} < T_s \end{cases} \quad (1)$$

$$T_{sI} = T_v \times \frac{(e - 0.5g)}{e + g} \quad (2)$$

$$T_{sII} = \frac{T_v}{\lambda \times q} \quad (3)\ ;$$

$$T_v = N_0 = 0.75 \times \sigma_y \times A_e \quad (4)$$

$$q = 1 - p \quad (5)$$

$$p = \frac{C_b}{C_b + C_c} \quad (6)$$

$$\lambda = \left(1 + \frac{g}{0.7e}\right) \quad (7)$$

$$C_f = \frac{E}{2t_F}\left\{\frac{\pi}{4} + \frac{\pi}{8} d_w (D_A - d_w)\left[\left(\sqrt[3]{\frac{2t_F \cdot d_w}{D_A^2}} + 1\right)^2 - 1\right]\right\} \quad (8)$$

$$C_w = \frac{\pi \cdot E \cdot (d_{wo} - d_{wi})^2}{4t_w} \quad (9)$$

Here:

T_p : Axial force of bolt ;
T_s : Tensile force on steel tube;
N_0 : design axial force;
T_v : Initial axial force of bolt;
e : Distance between the end of flange and bolt;
g : Distance between steel tube and bolt ;

C_b : Bolt - Tensile spring constant;
C_c: Flange - Compressive spring constant;
p : Inside and outside force ratio ;
λ : Compensated leverage ratio;
σ_y : Yield strength stress of bolt;
A_e : Effective cross-sectional area of screw;
C_f : Compressive spring constant of flange
C_w : Compressive spring constant of washer
d_s : Shaft diameter of bolt
d_w: Load bearing surface diameter
d_h : Diameter of the bolt hole
d_{wo} : Outside diameter of washer
d_{wi} : Inside diameter of washer
t_F : Width of flange
t_w : Width of washer
E : Young modulus of steel
D_A : Bolt pitch

2. *Petersen collapse mechanism:* [1]

Collapse mechanism 1: Non-deformation

Collapse mechanism 2: Tensile force in bolt exceed the allowable tensile force by the lever reaction force (Pr). Plastic hinge occurs at local of tubular body

Collapse mechanism 3: Plastic field occurs at local of steel tube and the hole's inner of bolt. The stress in bolt reached to the Yield point stress. With the development of enlarged wind turbine, people began using the flange joints that exceed the scope of the guideline formula with FEM analysis in basically. Therefore, they perform to revise the strength evaluation formula. With this concept Petersen's evaluation [1], (GL for Design of Wind turbine Support Structures and Foundations, p.267, 268) formula has been used widely. In this formula Petersen has considered that allowable yield strength of flange have been divided in three collapse mechanism. (Figure.3)

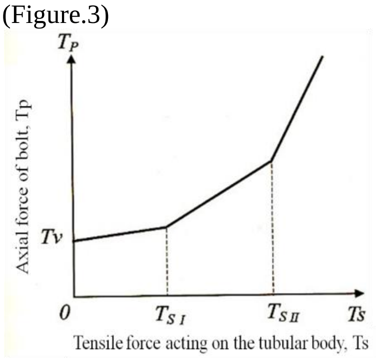


Fig. 1. Schmidt –Neuper diagram[2]

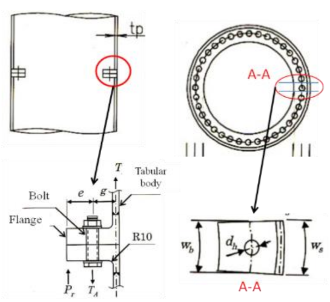


Fig.2. Detailed diagram of L-flange joint

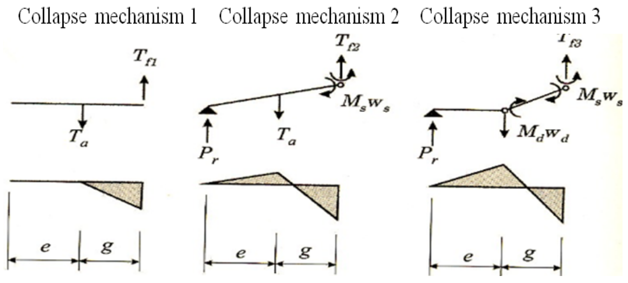


Fig.3. Petersen's collapse mechanism [3]

3. Seidel collapse mechanism[6] [7]: The collapse at the limited status can either appear by reaching to the resistance in bolt and flange or both of them at the same time, which are the same failure modes 1 – 3 by Petersen[1], see Fig.3. Seidel [6][7] then make more clearly between collapse mode in flange at axial the bolt or the washer and called these collapse mechanism 4 and 5 instead of 3. As Fig. 4 shows that the axial force and tension force in steel tube is nonlinear and can be divided into four ranges.

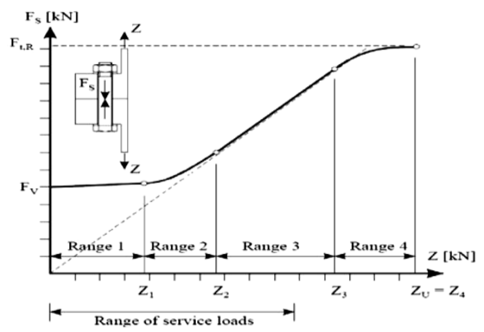


Fig. 4. Nonlinear relationships between axial force in bolt and tension force in steel tube with flange connections

Range 1: Approx, linear curve, stresses between flanges are reduced while contact zone is closed. *Range 2*: flange started separate *Range 3*: flange connection separated with slope due to loads geometry. *Range 4*: Plastic hinge in bolts and/or flange until collapse mechanism of connections. The tension in bolt depends nonlinearly on the tension force as the connection has pre- tension bolts. The graph show the nonlinear correlation of external load and tension force in the bolt shown in Fig. 4. The response is the same for the bending moment in the bolt.

B. FE- Analysis of a partof ring flange – bolt joint (L flange joint)

1. Description of the 3D FE Model:

The analysis is created by using ABAQUS 10.6.2. Different variants due to interaction as shown in Fig. 5 have been compared for the L flange joint with one bolt (L model) model. One variant uses interaction between washer, flange and bolt in symmetry. The connection between bolt head and washer is rigid. The else of variant is using interaction like a rigid connection with Link-elements in the plane of symmetry and analysis time is less.

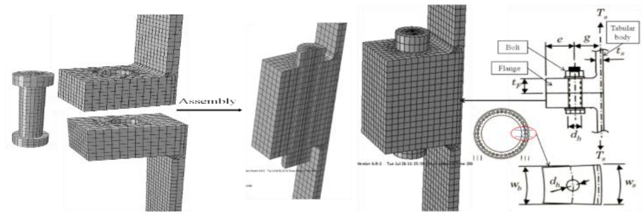


Fig. 5. The modeling apart L flange - joint with one bolt

The elastic – plastic hinge analysis have use a bi-linear stress-strain relationship due to the yield strength of the flange and steel tube. FEM analysis for bolt uses a constant cross-section base on the total length, the yield strength is the same with the plastic resistance of the bolt that equals to tension resistance in Eurocode 3 [2, Table 6.5.3].

The FEM Model with interactions could be verified by comparison with experimental results from Wanzek [3] and Petersen [1]. The Petersen [1] experiments cover medium flange thicknesses from 20 to 50mm. The FEA with interaction shows good agreement for all flanges which can be reliable.

2. Parametric FEM analysis for various flanges (L model)

A parametric FEM analysis has been created to show differences between calculation using S-N formula and the two of FEM variants for the L model. Fig. 6 shows the dimension of flange geometry. Thickness of FEA flange is 65 mm. The results show in Table-I. It has good results for flange thicknesses above 50mm due to collapse mechanism 2 (see Fig. 3).

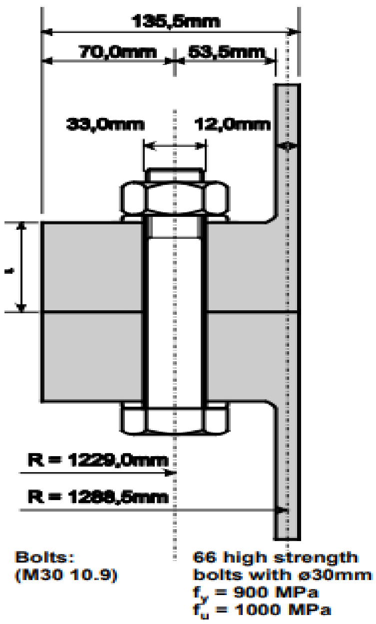


Fig. 6. Parameter of various flange

With thickness of 25mm, FEA model results are less than 50% of the result from the nonlinear FE-calculation.

The collapse mechanism got from the S-N fomular agree with FEA results for thick flanges.

Table- I: Ultimate load acc. to different calculation methods

Flange thickness (tF)	Using S-N formular		FEA	
	S-N fomular	Collapse mechanism	Interaction	No interaction
mm	KN	-	KN	KN
25	94,4	3	203	210
30	127,7	3	253	280
35	166,7	3	297	299
45	260,4	2	299	299
65	304,8	2	299	300
100	304,8	2	312	300

3. *Enhancement of the Schimidt – Neuper method*

To improve the calculation of bearing loading for thin flanges with the (S-N formula), the collapse mechanisms of the FEA were analyzed. The distribution of the stress due to limited status shows that bending resistance in flange supported by the contribution of moment in the interaction effected by tensile force(Fig.7). The bearing loading capacity from the S-N formula is too low because only considering a part of flange (L model) contribute to the plastic moment resistance (Fig. 7). A better approximation should be considered contribution of the bolt's contact pressure in calculation of the moment resistance.

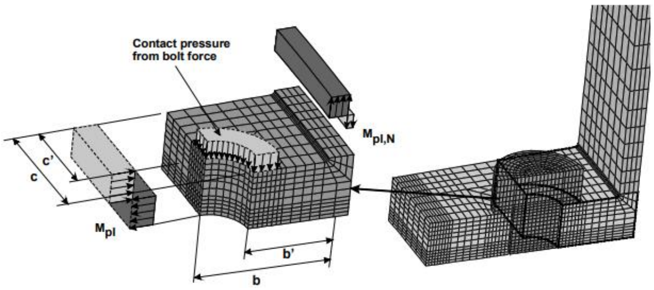
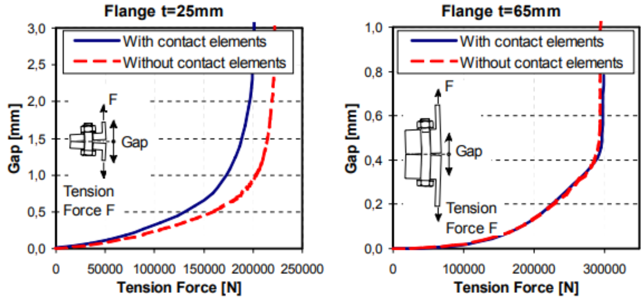


Fig. 7: Stress distribution in flange at ultimate limit state

4. *Effects of model on deformation behavior*

Deformation behavior of the two FEA variants for L model is important for the response of the total ring flange joint model. In part 2 ultimate bearing loading capacities of thick ring flanges can be considered by second variant. The total ring flange – bolt joint can be made the model without interaction predicts deformations accurately. Load-gap width-curves in Fig. 8 show the behavior of the different variants. The model without interaction effected much for the thin flange with t = 25mm, so assuming that the deflections from the model with interaction elements are correct. However, the deflections are in good agreement for thick ring flange (t = 65mm). The same applies to the bolt force so that the L flange – bolt joint model without interaction can be used to build up the FEA of the total ring flange- bolt joint with thick ring flange.



a) Comparison for flange t = 25mm b) Comparison for flange t = 65mm

Fig.8 Effect of model accuracy on gap widths in dependency of tension force

C. FE-Analysis of total ring flange – bolt joint

The total ring flange – bolt joint is created with length of 5000mm of steel tube. FEA model helps to determine tension forces in bolt and stresses in steel tube and flange under concurrent shear force and bending for the total ring flange – bolt joint. Fig. 9 shows that the tension forces in steel tube for the L flange – bolt joint model and the axial force in bolt from the total ring flange – bolt model. The bending stress from the total flange transfers to a tension force by multiplying the maximum bending stress with the appropriate area from the steel tube.

Axial forces in bolts are in good agreement for low tension forces. For separation of the flange connection, axial force in bolts in the total flange is below the axial force determined from L flange model. This behavior can be expected much because the parts of the flange (L flange – bolt joint) which are opening have a lower stiffness than the parts that are still in contact.

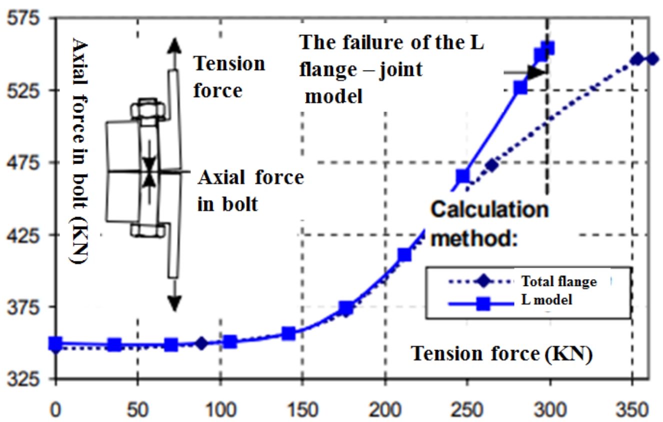


Fig. 9 Bolt force in dependency of tensile force

The separation of the ring flanges also one reason due to some redistribution of stresses in the steel tube. Stresses at the tension side are less than according linear theory, while at the compressed side are almost the same. Therefore, the neutral axis is near the compression side, but the deflection regarding the decrease of the maximum stresses at the tensile side between FEA model and theory are small (10%). The large decrease of stresses, so axial force in bolt at the tension side which is determined by Ebert and Bucher [4] from a ring model, does not appear. The bearing loading capacity of the total ring flange – bolt joint can be considered higher than L flange. The increase of bearing loading capacity can be accompanied by large plastic deformation in bolts. The real bearing loading capacity are not be limited by strength criteria but by allowable deformations and strains, particularly in the bolts.

D. Parametric study for different ring flange – bolt joint in case concurrent of shear force and bending

1. Ring flange – bolt joint model

The joints using flanges and bolts is simulated for 3 different diameter pipes of different sizes and the tree map is shown the way to determine the suitable ratio for thickness of flanges (t_f), diameter of bolt (d_s), thickness of steel tube in Fig. 10

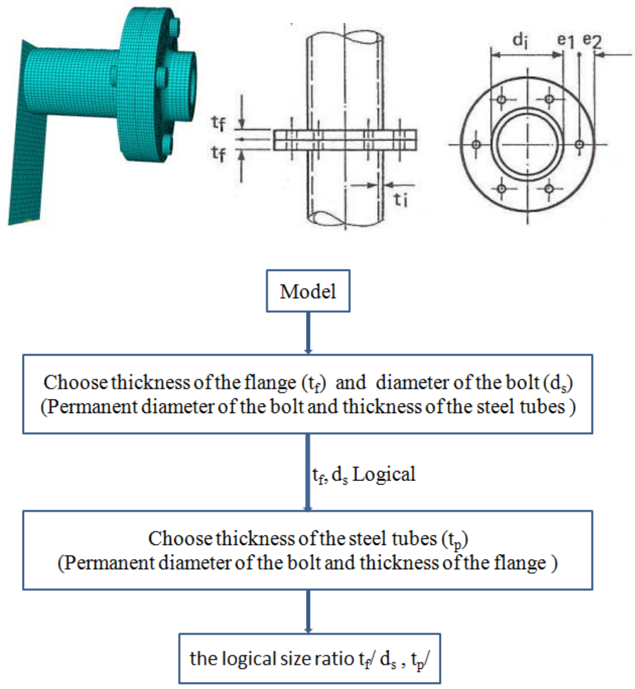


Fig. 10. Model of ring flange –bolt joint

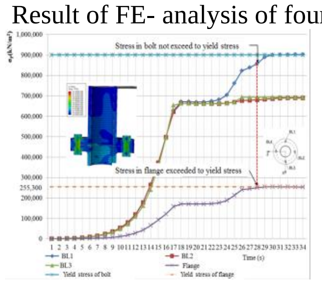
2. *Small size of ring flange – bolt joint (114.3x3.5mm)*

- Number of connecting bolt: 4;
- Diameter bolt: ds= 20mm

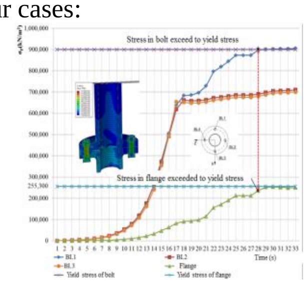
a. Choose logical size ratio between thickness of the flange and diameter of the bolt

- Specifications of 4 models:
  - Case 1: ds=20mm; t_f =20mm (t_f/ds=1,00)
  - Case 2: ds=20mm; t_f =22mm (t_f/ds=1,10)
  - Case 3: ds =20mm, t_f =25mm (t_f/ds=1,25)
  - Case 4: ds =20mm, t_f =28mm (t_f/ds=1,40)

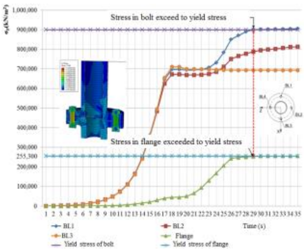
Result of FE- analysis of four cases:



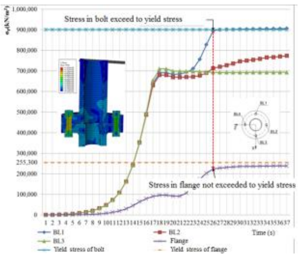
Case 1:d_s= 20mm, t_f=20mm (t_f/d_s =1,00)



Case 2: d_s= 20mm, t_f=22mm (t_f/d_s =1,10)



Case 3: d_s= 20mm, t_f=25mm (t_f/d_s =1,25)



Case 4: d_s= 20mm, t_f=28mm (t_f/d_s =1,40)

Fig.11. FE – Analysis results of small size ring flange – bolt joint

From the Fig. 11, with case 2 and case 3 (t_f= 22mm and t_f= 25mm **)**, stress in the bolt reach of Tensile strength limit (900000kN/m^2), besides stress in the flange reach of Tensile strength limit (255300 kN/m^2), the size ratio between the thickness of the flange and diameter of the bolt:

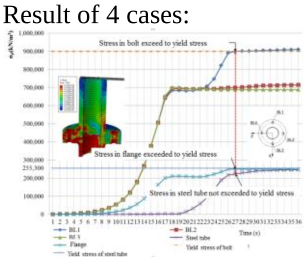
$$1{,}00<t_f/d_s<1{,}40$$

b. Choose logical size ratio between thickness of the steel tubes and diameter of the bolt

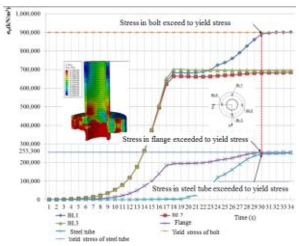
With the size ratio between thickness of the steel tubes and diameter of the bolt selected ($1.00<t_f/ds<1.40$), find the reasonable size for the thickness of the steel tubes and diameter of the bolt

- Specifications of 4 models:
  - Case 5: d_s= 20mm, t_f=22mm, t_p= 8mm (t_f/d_s =1,10; t_p/d_s =0,40)
  - Case 6: d_s= 20mm, t_f=22mm, t_p= 10mm (t_f/d_s =1,10; t_p/d_s =0,50)
  - Case 7: d_s= 20mm, t_f=22mm, t_p= 12mm (t_f/d_s =1,10; t_p/d_s =0,60)
  - Case 8: d_s= 20mm, t_f=22mm, t_p= 14mm (t_f/d_s =1,10; t_p/d_s =0,70)

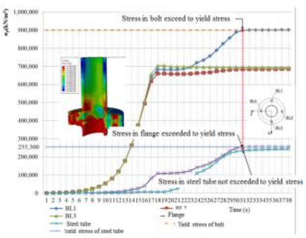
Result of 4 cases:



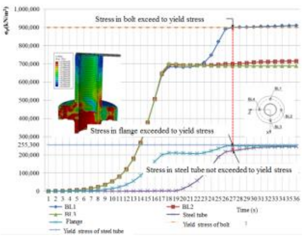
Case 5: d_s= 20mm, t_f=22mm, t_p= 8mm (t_f/d_s =1,10; t_p/d_s =0,40)



Case 6: d_s= 20mm, t_f=22mm, t_p= 10mm (t_f/d_s =1,10; t_p/d_s =0,50)



Case 7: d_s= 20mm, t_f=22mm, t_p= 12 mm (t_f/d_s =1,10; t_p/d_s =0,60)



Case 8: d_s= 20mm, t_f=22mm, t_p= 14 mm (t_f/d_s =1,10; t_p/d_s =0,70)

Fig.12. FE – Analysis results of small size ring flange – bolt joint

From the Fig.12, with case 6 (d_s= 20mm, t_F=22mm, t_p= 10mm**)**, stress in the steel tubes are close upon tensile strength limit, besides stress in the bolt and flange reach of Tensile strength limit. The size ratio between the thickness of the steel tubes and diameter of the bolt:

$$0{,}40<t_p/d_s<0{,}60$$

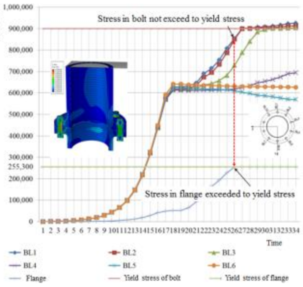
3. *Medium size of ring flange – bolt joint (267.4x6.0mm)*

- Number of connecting bolt: 10;
- Diameter bolt d_s= 22mm.

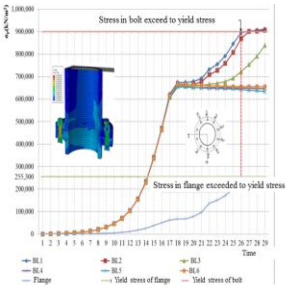
a. Choose logical size ratio between thickness of the flange and diameter of the bolt

- Specifications of 4 models:
  - Case 9: d_s=22mm; t_f =22mm (t_f/d_s=1,00)
  - Case 10: d_s=22mm; t_f =25mm (t_f/d_s=1,14)
  - Case 11: d_s =22mm, t_f =28mm (t_f/d_s=1,27)
  - Case 12: d_s =22mm, t_f =30mm (t_f/d_s=1,36)

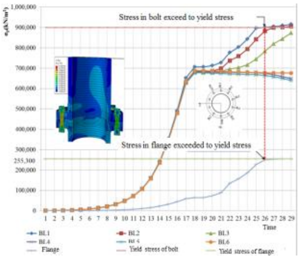
Result of 4 cases:



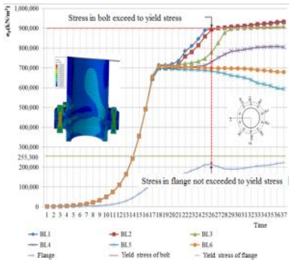
Case 9: d_s= 22mm, f_F=22mm (t_f/d_s =1,00)



Case 10: d_s= 22mm, t_f=25mm (t_f/d_s =1,14)



Case 11: d_s= 22mm, t_f=28mm (t_f/d_s =1,27)



Case 12: d_s= 22mm, t_f=30mm (t_f/d_s =1,36)

Fig.13. FE – Analysis results of medium size ring flange – bolt joint

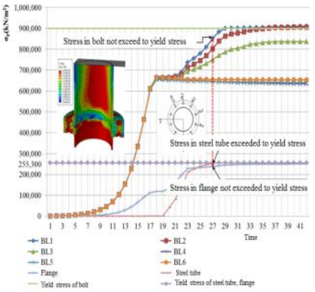
From the Fig.13, with case.10 and case.11 (t_f= 25mm and t_f= 28mm **)**, stress in the bolt and flange reach of Tensile strength limit. The size ratio between the thickness of the flange and diameter of the bolt: **$1{,}00<t_f/d_s<1{,}36$**

b. Choose logical size ratio between thickness of the steel tubes and diameter of the bolt

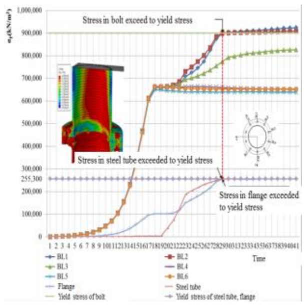
With the size ratio between thickness of the steel tubes and diameter of the bolt selected ($1.00<t_f/d_s<1.36$), find the reasonable size for the thickness of the steel tubes and diameter of the bolt

- Specifications of 4 models:
  - Case 13: d_s= 22mm, t_f=25mm, t_p= 10mm (t_f/d_s =1,14; t_p/d_s =0,45)
  - Case 14: d_s= 22mm, t_f=25mm, t_p= 12mm (t_f/d_s =1,14; t_p/d_s =0,55)
  - Case 15: d_s= 22mm, t_f=25mm, t_p= 15mm (t_f/d_s =1,14; t_p/d_s =0,68)
  - Case 16: d_s= 22mm, t_f=25mm, t_p= 18mm (t_f/d_s =1,14; t_p/d_s =0,82)

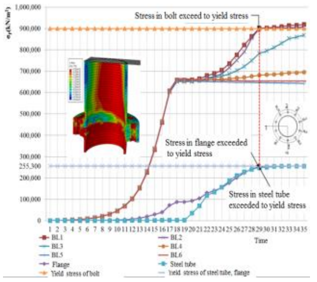
Result of 4 cases:



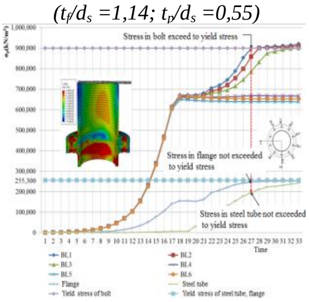
Case 13: d_s= 22mm, t_f=25mm, t_p= 10mm (t_f/d_s =1,14; t_p/d_s =0,45)



Case14: d_s= 22mm, t_f=25mm, t_p= 12mm (t_f/d_s =1,14; t_p/d_s =0,55)



Case 15: d_s= 22mm, t_f=25mm, t_p= 15mm (t_f/d_s =1,14; t_p/d_s =0,68)



Case 16: d_s= 22mm, t_f=25mm, t_p= 180mm (t_f/d_s =1,14; t_p/d_s =0,82)

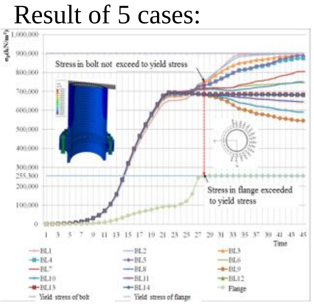
Fig.14. FE – Analysis results of medium size ring flange – bolt join

From the Fig. 14, with case 14 and case 15 (d_s= 22mm, t_F=25mm, t_p= 12mm and d_s= 22mm, t_F=25mm, t_p= 15mm**)**, stress in the steel tubes are close upon tensile strength limit, besides stress in the bolt and flange reach of Tensile strength limit. The size ratio between the thickness of the steel tubes and diameter of the bolt:

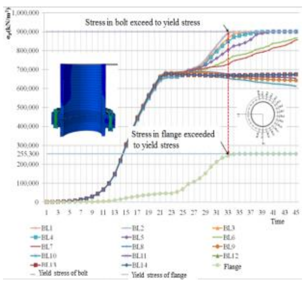
$0,45<t_p/d_s< 0,82$

4. *Large size of ring flange – bolt joint (406.4x12.7mm)*
- Number of connecting bolt: 26;
- Diameter bolt d_s= 24mm.

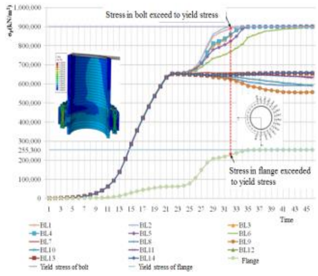
a. Choose logical size ratio between thickness of the flange and diameter of the bolt
- Specifications of 5 models:
  - Case 17: d_s=24mm; t_f =25mm (t_f/d_s=1,04)
  - Case 18: d_s=24mm; t_f =28mm (t_f/d_s=1,17)
  - Case 19: d_s=24mm; t_f =30mm (t_f/d_s=1,25)
  - Case 20: d_s=24mm; t_f =34mm (t_f/d_s=1,42)
  - Case 21: d_s=24mm; t_f =36mm (t_f/d_s=1,50)
- Result of 5 cases:



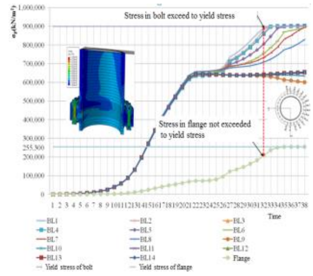
Case 17: d_s=24mm; t_f =25mm (t_f/d_s=1,04)



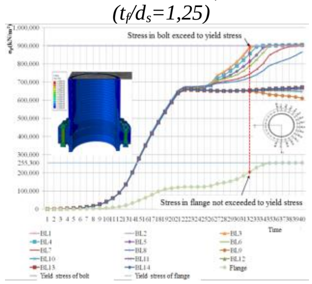
Case18: d_s=24mm; t_f =28mm (t_f/d_s=1,17)



Case 19: d_s=24mm; t_f =30mm (t_f/d_s=1,25)



Case 20: d_s=24mm; t_f =34mm (t_f/d_s=1,42)



Case 21: d_s=24mm; t_f =36mm (t_f/d_s=1,50)

Fig.15. FE – Analysis results of large size ring flange – bolt join

From the Fig.15, with case 18 and case 2.19 (t_f= 28mm and t_f= 30mm **)**, stress in the bolt and flange reach of Tensile strength limit. The size ratio between the thickness of the flange and diameter of the bolt:

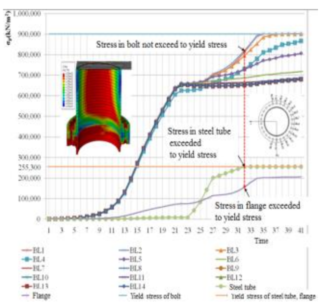
$1,04<t_f/d_s< 1,42$

\

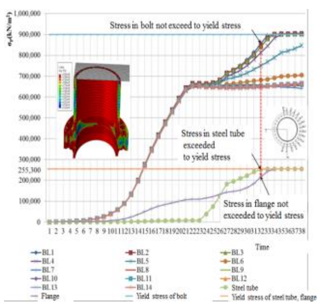
b. Choose logical size ratio between thickness of the steel tubes and diameter of the bolt

With the size ratio between thickness of the steel tubes and diameter of the bolt selected ($1,04<t_f/d_s<1,42$), find the reasonable size for the thickness of the steel tubes and diameter of the bolt
- Specifications of 4 models:
  - Case 22: d_s= 24mm, t_f=28mm, t_p= 18mm (t_f/d_s =1,17; t_p/d_s =0,75)
  - Case 23: d_s= 24mm, t_f=28mm, t_p= 20mm (t_f/d_s =1,17; t_p/d_s =0,83)
  - Case 24: d_s= 24mm, t_f=28mm, t_p= 22mm (t_f/d_s =1,17; t_p/d_s =0,92)
  - Case 25: d_s= 24mm, t_f=28mm, t_p= 25mm (t_f/d_s =1,17; t_p/d_s =1,04)

Result of 4 cases:



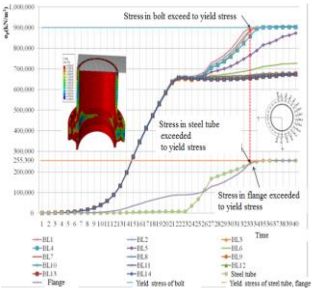
Case 22 d_s= 24mm, t_f=28mm, t_p= 18mm (t_f/d_s =1,17; t_p/d_s =0,75)



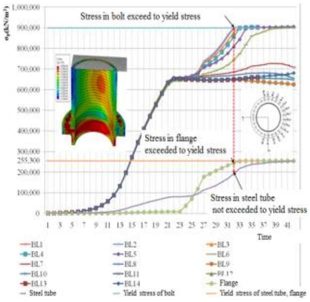
Case 23: d_s= 24mm, t_f=28mm, t_p= 20mm (t_f/d_s =1,17; t_p/d_s =0,83)

Retrieval Number: A2224109119/2019©BEIESP
DOI: 10.35940/ijeat.A2224.109119
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



Case 24: d_s= 24mm, t_f=28mm, t_p= 22mm
(t_f/d_s =1,17; t_p/d_s =0,92)



Case 25: d_s= 24mm, t_f=28mm, t_p= 25mm
(t_f/d_s =1,17; t_p/d_s =1,04)

Fig.16. FE – Analysis results of large size ring flange – bolt join

From the Fig.16, with case 24 (d_s= 24mm, t_F=28mm, t_p= 22mm **)**, stress in the steel tubes, bolt and flange reach of Tensile strength limit. The size ratio between the thickness of the steel tubes *and* diameter of the bolt:

$0,83<t_p/d_s< 1,04$

III. CONCLUSION

1. Various methods to determine the limit bearing loading capacity of ring flange – bolt joint are considered. The simplified design method proposed by S-N formula [2] for L flange – bolt joint prove good results for thick ring flanges, but not good for thin ring flanges. So the considering the effects of plastic moment in this method attain better results for thin ring flanges. The bearing loading capacity predicted on linear distribution of loading can be determined at an individual L flange model considered failure, is much lower than total model, due to redistribution.
2. In case of Small size tube simulation, the logical size ratio between thickness of the flange, diameter of the bolt and thickness of the steel tube is:

$1,00<t_f/d_s< 1,40$

$0,40<t_p/d_s< 0,60$

3. In case of medium tube simulation, the logical size ratio between thickness of the flange, diameter of the bolt and thickness of the steel tube is:

$1,00<t_f/d_s< 1,36$

$0,45<t_p/d_s< 0,82$

4. In case of large tube simulation, the logical size ratio between thickness of the flange, diameter of the bolt and thickness of the steel tube is:

$1,04<t_F/d_s< 1,42$

$0,83<t_p/d_s< 1,04$

ACKNOWLEDGMENT

This journal is a part of my research project (B2017-15) Ministry of Education and Training, Viet Nam
I would like to thank the supporting from Ministry of Education and Training of Viet Nam, The University of Da Nang (UD), Science Technology and Environment Department, University of Science and Technology (DUT) to help me finishing this research project well.

REFERENCES

1. Petersen,CH.:Steel construction, Braunschweig : Vieweg-Verlag,1988
2. Eurocode 3: Design of Steel structures; Part 1-1: General rules and rules and buildings.
3. Wanzek, T.: Zu Theorie, Numerik und Versuchen verformbarer Anschlußkonstruktionen. Berichte aus dem Konstruktiven Ingenieurbau der Universität der Bundeswehr München 97/7. München 1998 (in German)
4. Ebert, M.; Bucher, C.: Stochastical nonlinear study of preloaded bolts under wind load. Braunschweig 1997 (in German)
5. Schmidt, H.,Neuper,M.: On the elastostatic behavior of an eccentrically tensioned L-joint with pre-stressed bolts,Stahlbau,66,pp.163-168,1997
6. Heistermann, C., Husson, W., Veljkovic, M.: "Flange connection vs. friction connection in towers for wind turbines", Proc. of Nordic steel and construction conference (NSCC 2009), pp. 296 – 303, Malmö, Sweden, 2009
7. Seidel, M.: "Zur Bemessung geschraubter Ringflanschverbindungen von Windenergieanlagen",Dissertation, Universität Hannover, Institut für Stahlbau, 2001

AUTHORS PROFILE

Le Anh Tuan, Assistant Professor, Department of Civil Engineering, University of Science and Technology, The University of Da Nang, Viet Nam

Education:

- 04/2010-03/2013: Yokohama National University - Doctor course in Civil Engineering
- 04/2011 – 03/2013: Yokohama National University - Leadership Development Program for Sustainable Living with Environmental Risks (YNU-SLER)
- 4/2008 – 03/2010 : Yokohama National University – Master course in Civil Engineering
- 9/2000 - 1/2005: Bachelor of Engineering (Civil and Industrial Engineering) Ho Chi Minh City University of Technology (HUT), Vietnam.

Working Experiments

- 2013 – now: Lecturer at Steel Structure Division of Civil Engineering and Industry Department – The University of Da Nang – University of Science and Technology
- 2015 – now: Director of The center for Risk Management and Safety Sciences, University of Danang (UD)
- 2017 – now: Vice - Director of Department of Science Technology and International Cooperation, DUT, UD