DOI: 10.38061/idunas.1039978

IDUNAS	NATURAL & APPLIED SCIENCES JOURNAL	2023 Vol. 6 No. 1 (1-8)

Investigation of The Effect of Adding a Support Sleeve to a Six-Bolt Steel Circular Pipe Connection Clip on Mechanical Properties

Research Article

M. Murat Yavuz [1*], **Osman Berk Buldanlıoğlu** [1]

[1]İzmir Democracy University, Faculty of Engineering, Mechanical Engineering Department, İzmir.

Author E-mails
murat.yavuz@idu.edu.tr
berkbuldanlioglu@gmail.com

*Correspondence to: M. Murat Yavuz, İzmir Democracy University, Faculty of Engineering, Mechanical Engineering Department, İzmir, Turkey.

DOI: 10.38061/idunas.1039978

Received: 22.12.2021; Accepted: 27.12.2022

Abstract

In this study, the effect of adding a support sleeve for a pipe connection connected with 6 bolts of equivalent spacing was investigated. The research was carried out with a package program that is widely used in finite element analysis. The mouth geometry used for bolts and connection has been simplified for ease of analysis. As a material, steel with standard features was used in the models and static analyses were made. Factors that the connection may encounter most in operating conditions; The axial tension between the pipes, the internal pressure within the pipe and the bending effect with an applied moment were investigated. In addition, pre-loading was applied as displacement to all 6 bolts for axial loading and 3 bolts for bending condition. In the results, the connection region was determined as the region where the stresses were concentrated under all different loading conditions, and it was seen that the applied support sleeve did not show any benefit in reducing the stresses. It was determined that the preload applied to the bolts increased the stresses. Preloading only had a limited positive effect on the bending behavior.

Keywords: Pipe connection, Bolt, Stress, Internal pressure.

1. INTRODUCTION

Various methods are used to connect pipes to each other. These methods are mostly carried out by means of mechanical and chemical elements. It is necessary to ensure a continuous contact between the connections and to cut off any external contact. This condition, which occurs after the connection is completed, must also be fulfilled if the fluid is transported. It is the most important condition that the fluid does not leak out in the pipe connection. In cases where mechanical and chemical resistance occurs in pipes connected mechanically or chemically and may occur during flow transport, this resistance must be between certain limits. The different methods used for connections in the literature have been researched and the mechanical problems and efficiency on them are summarized. Most of the failures (Jun et al., 2020) in pipelines with metal parts are corrosion based and the alkalinity of the passing water and the age of the pipe are important factors. Slippage (Tasbihgoo et al., 2004) in mating pipe threads is thought to be the source of noise and fluid leakage. It (Wittenberghe et al., 2011) is recommended that local effects be considered with the entire system for fatigue life investigations in threaded pipe connections. The contact stresses (Shahani and Sharif, 2009) occurring at the connection point of the drill pipe were examined and the highest stresses occurred in the most anterior thread that entered the pipe and in the tooth bed it came into contact with. When the preload effect is applied, the average stress increase is achieved and the stress amplitude is reduced, thereby reducing the effects caused by fatigue. Various mechanical connections (Zaghi and Saiid, 2011) formed in two-way pipe-pin hinges were investigated under earthquake occurrence and it has been observed that the bearing strength of concrete is up to two times higher than the compressive strength of concrete due to boundary effects. Loading capacity (Barsoum and Khalaf, 2015) has been increased by making 3 different pipe-flange designs. A damaged aluminum refrigerant pipe (Stevenson et al., 2017) was examined and found to be broken at the pipe weld. The discontinuous structure (Ren et al., 2018) in the welded joint and the fragile nature of the weld cause a large stress concentration. The effects of seismic effects (Zhao et al., 2022) on the buried gas pipeline under dynamic conditions were investigated and the failures in gaskets and flanges were investigated. In the results of the examination, the use of bolted flange connection is recommended. The pipe failure model (Winkler et al., 2018) that occurs in urban water distribution planning has been investigated and the magnitude of the problems that may occur in distribution has been shown. Leakage investigation (Zhang et al., 2021) was performed on steel wire reinforced polyethylene pipes and it was determined that the over-welded coupling sleeve caused leakage damage. A corroded pipe (Zhang et al., 2020) was repaired using composite material and the axial tensile and internal pressure behavior of the repaired pipe was investigated. Bolted joints were widely used, and preloading is a basic application of bolt connection to prevent the leakage. Bolt preloading (Sawa et al., 2003) was investigated on sealing of pipes at flange connections and the applied axial force was important to ensure the suitable clamping bolt force that was recommended by Pressure Vessel Research Council in USA. The provided connection (Sawa et al., 2006) between preloaded bolt-flange was analyzed for heat and internal pressure effects and connection performance decreased with increasing the temperature. As a result of heat increase on connection, the contact stresses increased. Bolted joints on pipe connections having flanges (Fukuoka and Takaki, 2001) were analyzed for different bolt numbers and stress values were given. Also spiral wound gaskets in bolted-flange connection of pipes (Fukuoka and Takaki, 2003) were analyzed and a uniform preloading values were determined with considering high non-linear stress-strain behavior. If the parameters; pipe diameter and flange thickness (Azim, 2013) were increased, bolt tension increased in the tension of bolts on connection of pipes. Flange thickness-width and diameter of bolt (Tafheem, 2012) have a dominant effect on bolt tension under bending loadings. The preloading was applied with a torque wrench and tightening values of torque wrench (Kondo et al., 2011) was analyzed which included tightening coefficient was given.

As a result of this study, the effect of the support sleeve that can be used was investigated and its effect on the mechanical properties was examined.

2. MATERIAL AND METHOD

Bolt connection is widely preferred in terms of ease of assembly and disassembly. One of the most common problems in these connections is the bending that occurs during the axisymmetric loading on the bolt. Another load that may come from outside to the connection area is the bending condition that commonly occurs in the bolts. In order to reduce bending and external influences, a collar attachment was included and mounted in the connection area using longer bolts. Figure 1 shows two pieces of pipe connected by bolts and their geometrical features. The cuff used is in the form of a flat and simple bracelet, and its dimensions are shown. Boundary conditions are like each other in case of different loading conditions such as axial tension, internal pressure effect and bending condition. In the case of axial tension, one of the free ends of the pipe is fixed and an axial tensile load of 1000 Pa is applied from the other end. In order to examine the internal pressure effect, the free ends of both necks were fixed, and a pressure of 1000 Pa was applied to the inner surface of the two pipes. To examine the bending condition, the free end of a pipe was fixed, and a pure moment of 120 Nm was applied from the other end. The parts are in full contact, and the contact surface is susceptible to friction. Friction was modelled in accordance with Columb's law of friction and a friction coefficient of 0.3 was determined for the interaction between surfaces. The results are expressed as the Von-Mises stress given in Eq. 1. The modulus of elasticity of the steel material used in the standard specification was determined as 200 GPa and the Poison ratio was 0.3. All solution results are performed in accordance with elastic boundary conditions.

$$\sigma_{VM} = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}} \tag{1}$$

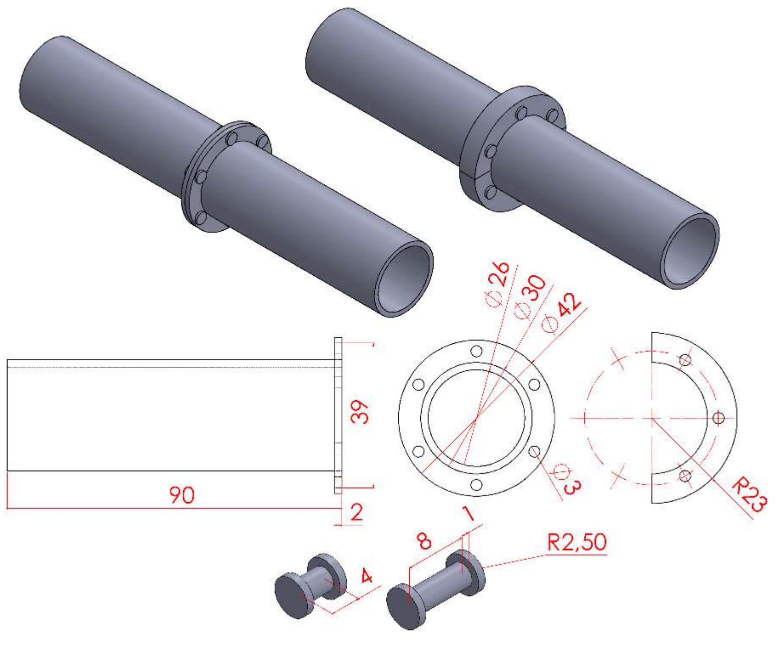

Figure 1. The geometry of the pipe joint and the joint support collar.

3. RESULTS AND DISCUSSION

In all results, a line contacting the inner surface of the pipes was created and results were obtained by using this line. Fig. 2 shows the stress results for the internally pressurized model. It is seen in the results that the stress is concentrated in the connection region. The applied support sleeve caused the stresses to increase more. Tensile value is approximately 3 times higher.

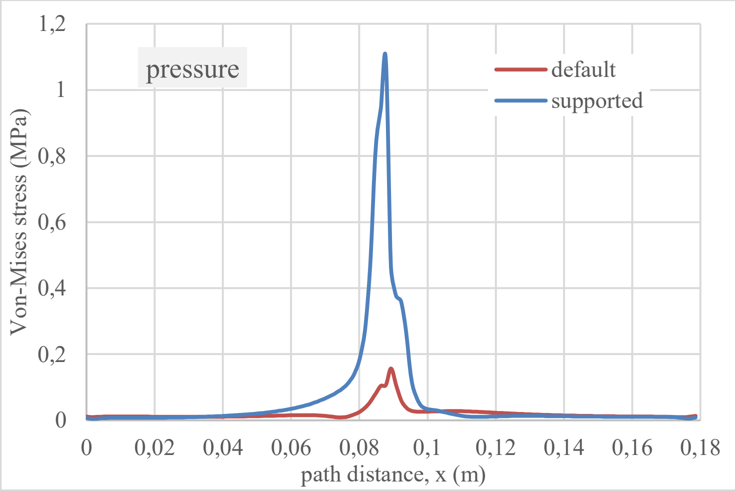

Figure 2. Stress distribution on the wall along the pipe direction in the application of in-pipe pressure.

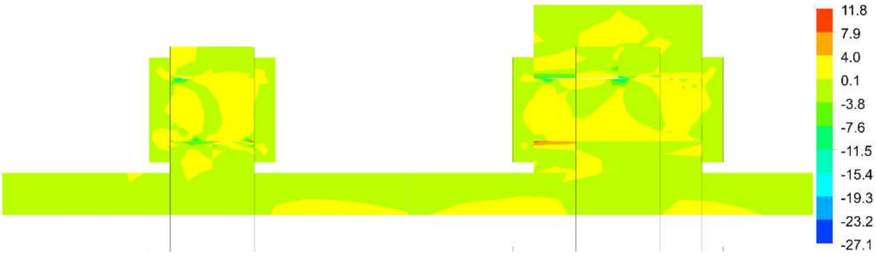

Figure 3. Normal stresses occurring in the middle of the pipe in the application of in-pipe pressure.

In Fig. 3, the stress contours formed as a result of the internal pressure are shown for the upper half of the pipes over a plane taken in the middle section. The stresses are given as axial stresses and the values are in the order of MPa. The stresses occurring in the bolt cross section in the normal connection are formed in the form of bending behavior. It is seen that the highest positive stress occurs at the contact corners of the bolt closest to the pipe body. In the support added structure, while stresses of similar values occurred in the bolt structure, the highest normal stress occurred along the entire slot hole length in the socket bed of the support used in contact with the bolt. In the bending state where the bolt size increases, there is more shape change, and this is seen in the added support piece.

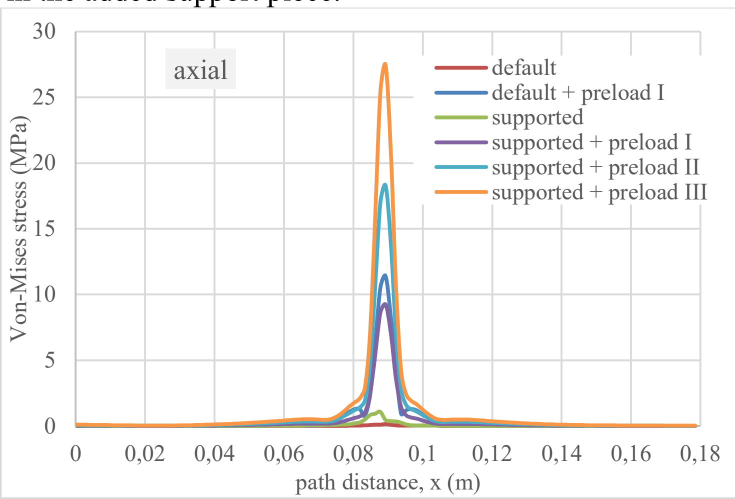

Figure 4. Stress distribution in the pipe wall in the axial tension of the pipe end

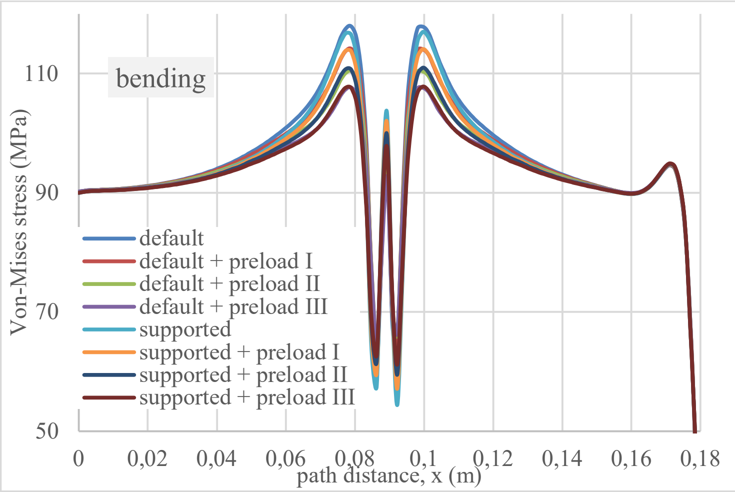

Figure 5. Stress distribution in the pipe wall for bending.

Fig. 4 shows the stress distribution for the axial tension condition. For the case of supported and straight bolt connection, the bolts are also preloaded with displacement condition. The displacements used in preloads I, II and III are 0.01 mm, 0.02 mm, and 0.03 mm. The bolt preload used generally caused the stresses to increase rather than decrease in axial tension. The stresses that occur in the normal bolt connection are lower than the part with the support used. On the other hand, stresses in the reinforced bolt connection for the preload I condition were lower than the normal bolt connection results. There is no region of stress concentration outside the connection region. Stress contours were similarly formed as normal stresses formed as a result of pressure.

Fig. 5 shows the resulting stresses for the bending condition. The preload condition used had an effect for the bending condition and reduced the results to a limited extent. In the results with support pieces, the stress value was less than the results with normal bolt connection. The rightmost side of the graph shows the moment effect applied at the free end and the leftmost side shows the stresses resulting from the support effect. The support stress from M×c/I is 90 MPa in the analytical solution and the finite element result in the graph is correct.

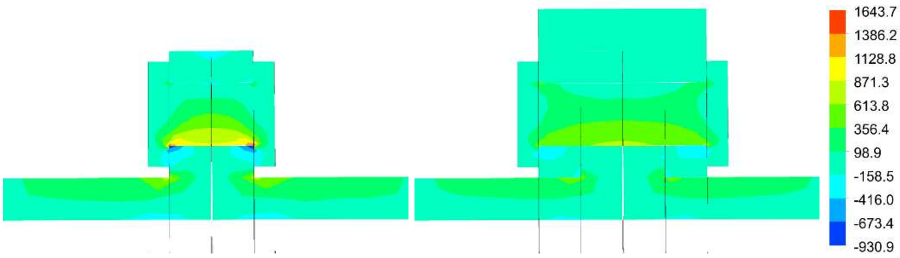

Figure 6. Normal stresses in the middle of the pipe in bending application (MPa).

Stress contours are shown in Fig. 6. The bending condition exhibited simply supported beam behavior for the pipe section and bolt piece.

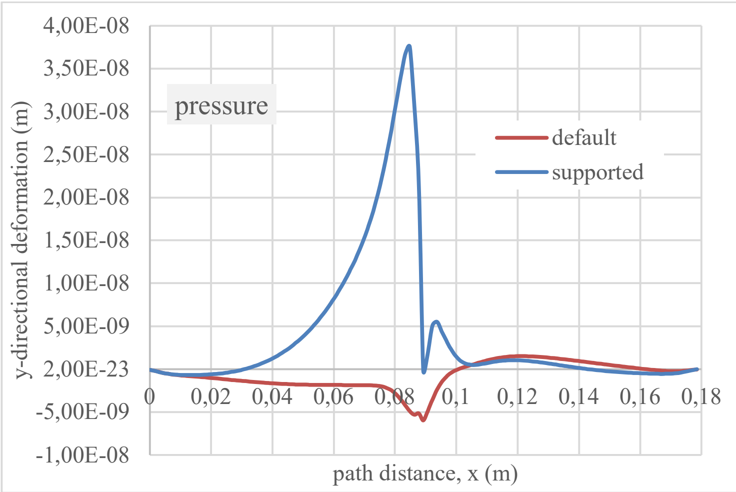

Figure 7. Deformation distribution on the wall along the pipe direction in the application of in-pipe pressure.

The deformation plot is shown in Fig. 7 for pressure. The support used provided a positive deformation of the inside of the pipe in the outer direction. For the normal connection situation, it is seen that the pipe corners are bent locally towards the inside of the pipe at the junction. The deformation is higher in the supported connection.

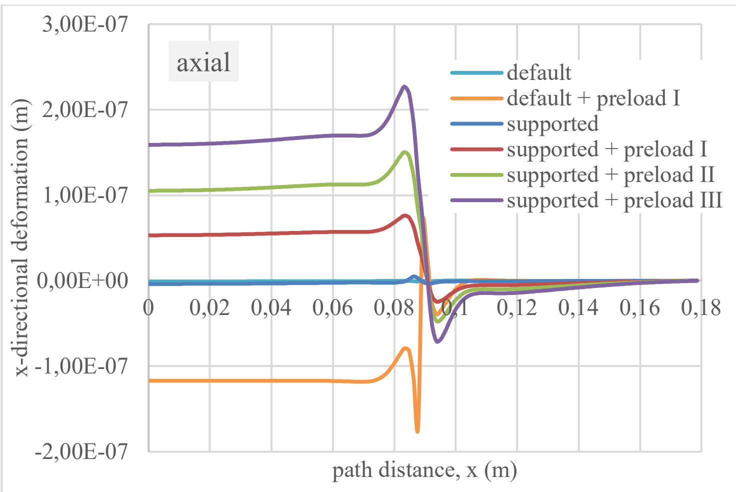

Figure 8. Deformation distribution in the wall along the pipe direction in axial drawing application

The deformation results for the axial tensile condition are shown in Fig. 8. It is seen that the deformation is more in the supported part. It was observed that the applied preload did not reduce the deformation. However, the axial deformation in the supported joint occurred positively. It is a negative effect for fluid leakage. This situation occurred in the negative direction for the normal bolt connection.

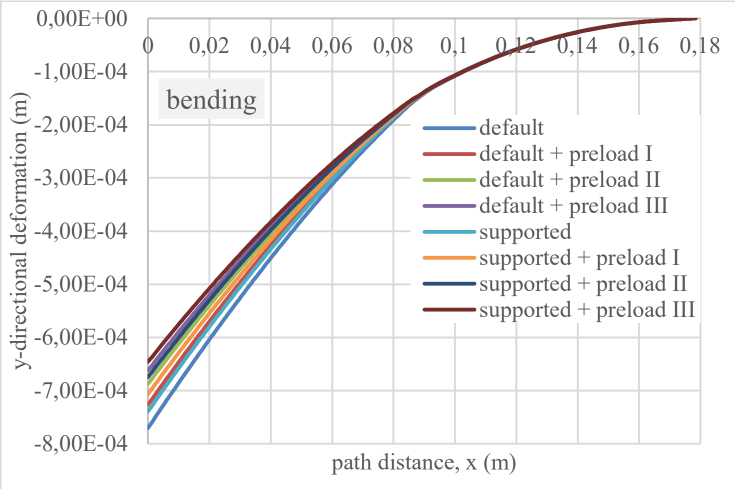

Figure 9. Deformation distribution on the wall along the pipe direction in bending application.

In Fig. 9, the deformation in the vertical direction is shown for the bending condition. Although the deformation results in the pipe section where the support is located after 0.9 m are similar, the bending situation seems to be dominant at the point where the 0-0.09-meter moment is applied. The highest deformation occurred in the normal connection condition. The applied preload reduced the deformation. The preload on the bolts was applied only for the 3 bolts in the upper part.

4. CONCLUSION

In this study, normal bolts and bolt connection with support ring were applied in connecting the pipes and their structural behavior was investigated under 3 different mechanical conditions. In general, the following findings were obtained in the results of the pre-loading of the bolts;

- In all different loading conditions, the joint zone is determined as the zone of concentration of stresses.
- The applied support sleeve caused the stresses to increase up to 3 times.
- Larger shape changes occurred in the bolts in the support sleeve used.
- The preloads applied to the bolts caused the stresses to increase in the axial tension condition.
- Preloads applied in case of axial tension caused mostly positive deformation of the joint and are negative for fluid leakage.

5. REFERENCES

1. Jun, J. H., Park, J. K., Bae, C. H. (2020). Factors affecting steel water-transmission pipe failure and pipe-failure mechanisms. Journal of Environmental Engineering, 146(6), 04020034.

2. Tasbihgoo, F., Caffrey, J. P., Masri, S. F. (2004). Nonlinear finite element analysis of a threaded pipe connection. ASME/JSME 2004 Pressure Vessels and Piping Conference, 173-179.

3. Wittenberghe, J. V., Baets, P. D., Waele, W. D., Galle, T., Bui, T. T., Roeck, G. D. (2011). Design characteristics that improve the fatigue life of threaded pipe connections. Sustainable Construction and Design, 2(2), 334-341.

4. Shahani, A. R., Sharif, S. M. H. (2009). Contact stress analysis and calculation of stress concentration factors at the tool joint of a drill pipe. Materials and Design, 30, 3615–3621.

5. Zaghi, A. E., Saiid, S. M. (2011). Bearing and shear failure of pipe-pin hinges subjected to earthquakes. American Society of Civil Engineers, 16(3), 340-350

6. Barsoum, I., Khalaf, A.M. (2015). Evaluation of a pipe-flange connection replacing fusion welding. Procedia Engineering, 130, 446-452.

7. Stevenson, M. E., Iwand, H. C., McDougall, J. L., Umberger, P. D., Wilkinson, J. A., Kenner, M. T., Stone, D. H. (2017). Failure analysis of an aluminum chiller pipe by experimental simulation and stress analysis. J Fail. Anal. and Preven., 17, 1090–1098.

8. Ren, F., Li, B., Tang, X. (2018). Failure analysis of collecting pipe head used in ammonia refrigerating system. IOP Conf. Series: Materials Science and Engineering, 382, 022101.

9. Zhao, K., Jiang, N., Zhou, C., Li, H., Cai, Z., Zhu, B. (2022). Dynamic behavior and failure of buried gas pipeline considering the pipe connection form subjected to blasting seismic waves. Thin-Walled Structures, 170, 108495.

10. Winkler, D., Haltmeier, M., Kleidorfer, M., Rauch, W., Tscheikner-Gratl, F. (2018). Pipe failure modelling for water distribution networks using boosted decision trees. Structure and Infrastructure Engineering, 14(10), 1402-1411.

11. Zhang, X., Hou, L., Li, H., Qi, G., Qi, D. (2021). Leakage analysis of steel wire reinforced polyethylene composite pipe used for wastewater transportation. Engineering Failure Analysis, 130, 105750.

12. Zhang, Y., Cheng, Z., Jia, Z. (2020). Failure loads analysis of corroded pipe repaired by composite material under tension and internal pressure. *Journal of Marine Engineering & Technology*.doi: 10.1080/20464177.2020.1826675.

13. Sawa, T., Matsumoto, M., Nagata, S. (2003). Effects of scatter in bolt preload of pipe flange connections with gaskets on sealing performance. ASME Pressure Vessels and Piping Conference, 20-24 July 2003, Cleveland, Ohio, USA.

14. Sawa, T., Takagi, Y., Yamada, K. (2006). Evaluation of the sealing performance in bolted flange connection under heat condition and internal pressure (the effect of scatter in bolt preloads). ASME Pressure Vessels and Piping Division Conference, July 23-27, 2006, Vancoucer, BC, Canada.

15. Fukuoka, T., Takaki, T. (2001). Finite element simulation of bolt-up process of pipe flange connections. Journal of Pressure Vessel Technology, Transactions of the ASME, 282- 287.

16. Fukuoka, T., Takaki, T. (2003). Finite element simulation of bolt-up process of pipe flange connections with spiral wound gasket. Journal of Pressure Vessel Technology, Transactions of the ASME, November 2003, 371-378.

17. Azim, R. (2013). An analytical investigation on bolt tension of a flanged steel pipe joint subjected to bending moments. International Journal of Engineering and Applied Sciences, 2(3), 71-81.

18. Tafheem, Z. (2012). Investigation on bolt tension of flanged pipe joint subjected to bending. Master of Science in Civil Engineering, Bangladesh University of Engineering and Technology, February 2012.

19. Kondo, K., Omiya, Y., Kobayashi, T., Sawa, T. (2011). Scatter of bolt preloads in pipe flange connection tightened by impact wrench and the effect on sealing performance. ASME International Mechanical Engineering Congress and Exposition, November 11–17, 2011 Denver, Colorado, USA.