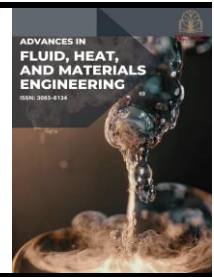




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# Stress and Deformation Analysis of Steel Sleeve Repair Welding Pipe

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### ABSTRACT

Sleeve repair welding (SRW) is a medium-sized pipeline repair task to minimize pipeline shutdowns. However, weldment quality and pipe burn-through were noted as concerns. Excessive residual loads and deformations were the primary cause of poor weld quality. This study aimed to find the ideal steel sleeve size and internal pipeline flow conditions for minimizing residual stresses and deformation. The test is carried out with a strain gauge as a measuring tool. The strain gauge used is a single-axis strain gauge, type FLA-5-11. To complete the objective of this study which is to identify the effect of steel sleeve welding on steel pipe, there are some results gathered. The analysis is based on the strain, stress, and deformation readings obtained from the strain gauge. The steel pipes were tested with different pressures, 2 psi, 4 psi, 8 psi, and 12 psi. Besides that, the strain gauge was also positioned with different orientations which are horizontal and vertical orientations to observe and compare the result with different orientations. All the results are taken from different positions on steel pipe which are at the top and bottom of the steel pipe, with sleeve repair and without SRW. The result demonstrates that steel pipe with SRW has less strain, stress, and deformation compared to steel pipe without SRW. Hence this shows that the steel repair method can help in reducing the bad effects of defects that happens in underground pipeline systems. It also shows that the effect of pressure in steel pipe happens to be more at the bottom of the steel pipe compared to at the top of steel pipe. These indicates that the steel SRW and reinforcement of steel pipe at the bottom of is important.

## 1. Introduction

Pipelines are typically made of carbon steel, and their dimensions can range widely due to the kind of pipeline and the purpose it serves. Natural gas pipeline networks are complex systems made up of many different units and subsystems with different architectures and purposes. Due to this complex system that is buried, it is very common for defects to occur. The defects can be categorized into two, which are mechanical and environmental. The environmental factors that cause defects in the pipeline system are corrosion, dent, and cracking, whereas manufacturing defect in the pipe body

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[1] is a type of mechanical damage. Mechanical damage is the leading cause of pipeline accidents, causing external damage at about 49.6%, manufacturing flaws at 16.5%, corrosion at 15.3%, and ground movement at 7.3% [2].

These defects are difficult to overcome due to the large complexity of the pipeline system and require a high cost to shut down the whole system for pipe repair works. Hence, several methods are introduced to overcome these defects without major shutdown. For pipeline fix maintenance, four repair methods have been categorized: non-critical repair, minor repair, moderate repair, and major repair work. Split sleeve repair was generally employed on medium-scale repairs where pipeline closure was not required. As a result, sleeve repair welding is proposed since the previous study had shown that it reduced integrity ramifications while preventing pipeline stoppage.

There are type A and Type B steel sleeves [3,4]. However, this study focused on a type B steel sleeve, which is pressure-containing, with each end fillet welded to the carrier pipe. The flaw repairing at 80 percent might be necessary including circumferentially orientated and leaking faults by choosing a type A steel sleeve. Type B Welded Sleeves are commonly utilized [5]. In SRW, two half-sleeves are built around the pipe portion with a longitudinal butt weld, and then the sleeve is attached to the pipe with a circumferential fillet weld. The sleeve welding process was modeled based on Shielded Metal Arc Welding (SMAW), which was widely recommended. Then, the electrode chosen, E7018, was based on the suitability of the SMAW process and used by a past study [6]. The steel sleeve repair welding is known as a challenging task requiring a skilled welder and equipment. There will be sufficient welding rods to complete the welds required along with adequate backup equipment such that should any item fail during the welding operations the replacement can be brought in to replace it immediately. A stand-by qualified welder will also be on hand

Several finite element (FE) simulations of SRW were undertaken over the past two decades to examine the transient temperature field, cooling rates, stress fields, and prediction of molten state utilizing thermo-mechanical elastic-plastic models. For example, Wang *et al.*, [7] have carried out a study on the effect of thermal on pipelines. Because of this, this study was carried out to investigate the stress and deformation that occurs in pipelines with and without steel sleeves with some manipulation such as position of strain gauge on the pipe and differential in pressure [8,9].

## **2. Methodology**

### **2.1 Material and Method**

The methods and procedure of the analysis are explained where the test is conducted using a strain gauge and water pump to give pressure inside the steel pipe. The test results are strain, stress, and deformation which vary in pressure and strain gauge orientations.

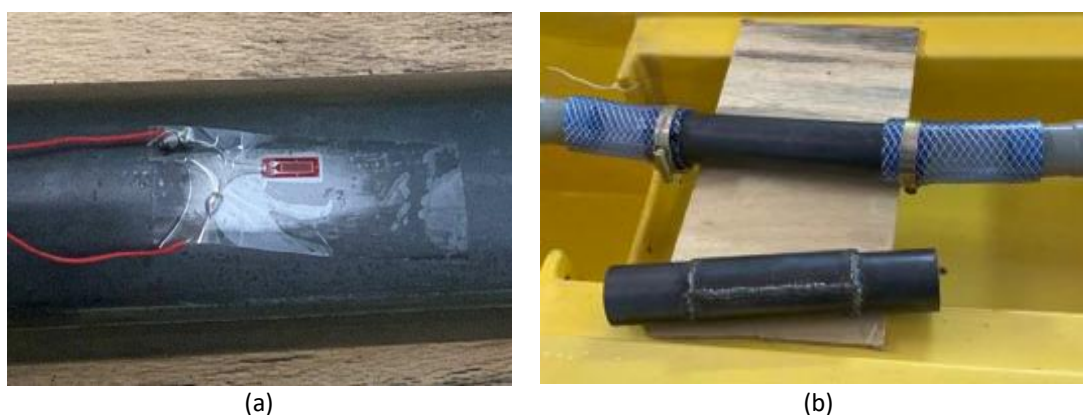
### **2.2 Strain Gauge Installation**

The process of attaching the gauge is divided into several minor parts and sections as mentioned by Ling *et al.*, [10]. Before gauge installation, the bar surface must be thoroughly clean. Acetone is reapplied to eliminate any dust that has accumulated on the surface. These stages are completed swiftly and smoothly to guarantee a secure connection. Gauge installation tape has two functions. It enables the gauge to be handled without touching it, and it assists in positioning the gauge on the specimen before gluing. The length of the tape should be between 2 and 3 inches, with the gauge centered on the strip. Applied one drop of CN adhesive to the seam where the peeled-back tape meets the steel. Using a smooth and continuous motion, slide a finger or thumb from the connected

end of the tape to the free end. Then the process is repeated to other positions on the steel total of four strain gauge positions.

### 2.3 Experimental Setup

After strain gauge is place on the steel surface well positioned to carry out the analysis. We set up the experiment which consist of fixing PVC hose pipe with coupling and attach the PVC braided hose to the steel pipe (Figure 1). The setup apparatus is PVC braided hose outer diameter 2.5-inch, PVC glue, PVC coupling 2.0-inch x 0.8 inch and pressure regulator with pressure gauge. The first step is to combine the small PVC braided hose with larger one using coupling and PVC glue at both side of the steel pipe. Then, attach the pressure regulator on the exit PVC hose. Next, connect the hose pipe to motor pump which allows the water pump to flow water with certain pressure in and out in constant flow.



**Fig. 1.** Experiment setup of sleeve pipe (a) Pressure gauge embedded (b) Pipe installation

### 2.4 Data Reading and Pressure Change

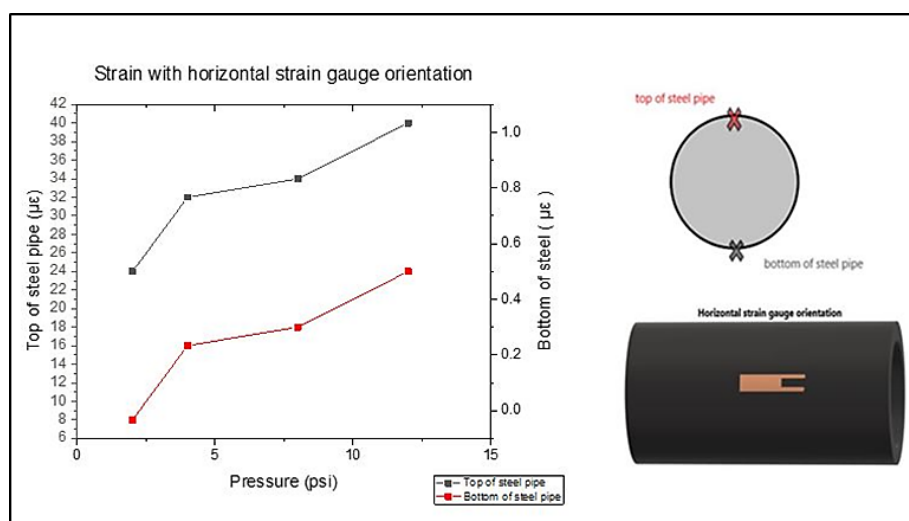
When the water is flowing through the steel pipe there is a pressure reading on the pressure gauge which is attached to the exit PVC braided hose. The pressure is due to the pump motor hose power. Now the pressure regulator is adjusted to differentiate into three vary pressure which is 2 psi, 4 psi, 8 psi, and 12 psi. The data is collected and noted for each different pressure from the data logger of the strain gauge.

## 3. Results

The study of steel sleeve repair method effects for underground pipeline system is carried out with a few analyses; stress, strain, and deformation. The experimental analysis is carried by using a hollow bar steel with and without steel sleeve repair with water as a stream flow inside the steel bar as the pressure element. The strain result in both conditions, with sleeve weld and without sleeve weld is discussed. The discussion is based on strain results obtained against two different orientations  $0^\circ$  and  $180^\circ$  with different pressures of 2 psi, 4 psi, 8 psi, and 12 psi. The discussion then continues with the correlation between deformation and two different orientations  $0^\circ$  and  $180^\circ$  with different pressures of 2 psi, 4 psi, and 8 psi. Following by stress analysis on steel pipe. The discussion is about the stress that is obtained on the steel pipe with and without the sleeve repair method. The stress is studied with a stress and strain graph to know the effects of the steel sleeve welding and the difference in the results of the orientation.

### 3.1 Strain Result on Steel Pipe with SRW

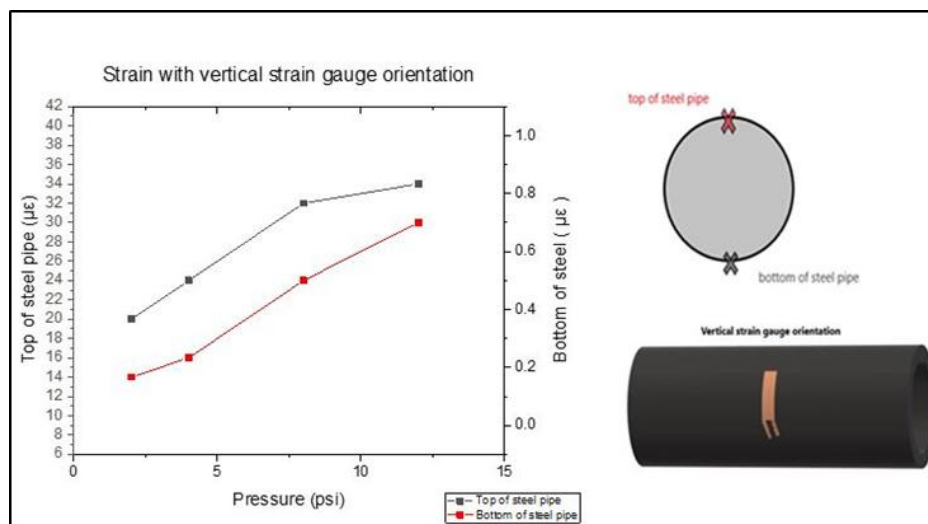
The test is done twice at the top of the steel and the bottom of the steel. The strain gauge is also positioned in two horizontal and vertical orientations. The test results are as follows. Figure 2 shows the results obtained on a steel pipe with sleeve repair. The strain gauge at horizontal ( $0^\circ$ ) orientation shows a graph with increasing trend for both tests at the bottom of the steel pipe and the top of the steel pipe. This indicates the strain increases simultaneously with pressure as per a previous study on strain and pressure on steel pipe manipulating the positions [11]. The graph shows the strain increases at higher values from the initial pressure to the second. Then it increases at a lower rate before increasing to a higher strain rate at the end pressure. This indicates that the pressure range of 4 psi to 8 psi with the difference of 2 psi doesn't give very large significant changes in the strain value. The maximum strain at the bottom and top is  $25 \mu\epsilon$  and  $40 \mu\epsilon$ , respectively. The maximum strain data indicated less significance at the top and bottom than steel pipe without sleeve repair. This was agreeable with the test conducted by the Australian pipeline, which can be concluded that the steel sleeve repair welding can significantly repair and strengthen the steel pipe [12].



**Fig. 2.** Strain with sleeve repair with horizontal orientation strain gauge

Figure 3 shows the strain on a steel pipe with SRW with a  $90^\circ$  vertical orientated strain gauge. The graph trend is increasing but not evenly with all four different pressures. The initial pressure, 2 psi, recorded the reading of strain  $14 \mu\epsilon$ , followed by 16, 24, and  $30 \mu\epsilon$  for 4 psi, 8psi and 12 psi, respectively. Hence, the strain reading drastically increased from the second pressure, 4 psi, to the last pressure, 12 psi. At the same time, the strain result of initial pressure to the second pressure shows a very slight increase of  $2 \mu\epsilon$  only. This is because the pressure rate is insufficient to increase the steel pipe strain significantly. It needs a certain amount of pressure to effect strain on the steel pipe [13]. Figure 2 and Figure 3 clearly show that the strain is higher at the top of the steel pipe compared to the bottom. This result is different from the steel pipe without SRW, which shows the strain is higher at the bottom of the steel. This situation occurs due to the gap between the welded sleeve, which may reduce the reading of strain.

The graph in Figures 2 and Figure 3 shows a small gap between the welded sleeve at the bottom of the steel, which causes the strain reading to be less than the top, indicating a lack of stiffness in this area. This occurrence can be related to the study carried out by Arifin *et al.*, [14]. Hence the strain results it shows that the steel pipe with SRW shows better in strength. The steel pipe with SRW shows less strain reading in both top and bottom of the steel compared to steel pipe without sleeve welding.



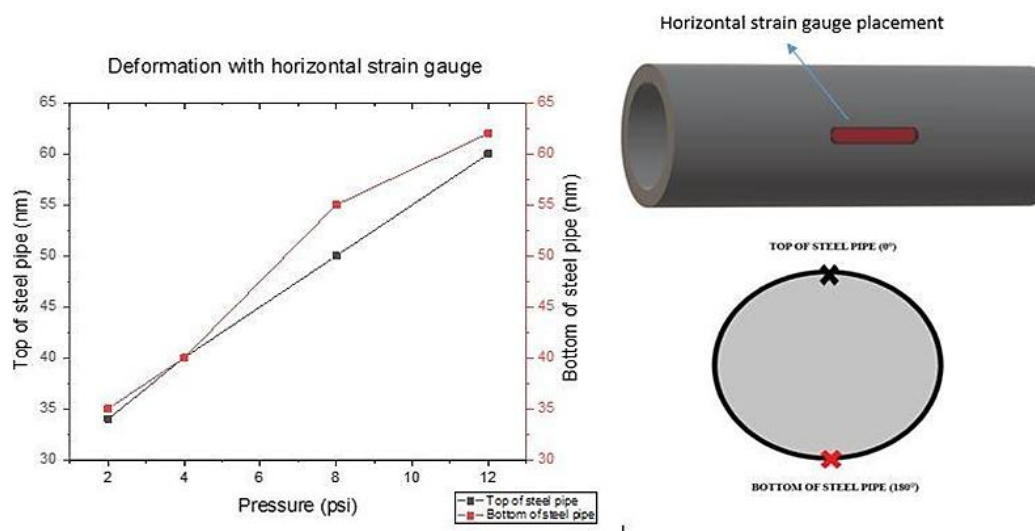
**Fig. 3.** Strain on steel sleeve with vertical orientation strain gauge

### 3.2 Deformation Result on Steel Pipe

The obtain deformation result indicated the deformation reaction of steel pipe upon pressure. This study is vital to ensure the maximum pressure the steel pipe can withstand and the effect of steel sleeve welding on the steel pipe. The sensitive used is in nanometer the deformation on the steel pipe is minimal due to very less pressured pump is used and under safety measures. The test is carried out on steel pipes with and without sleeve repair with different orientation of strain gauge.

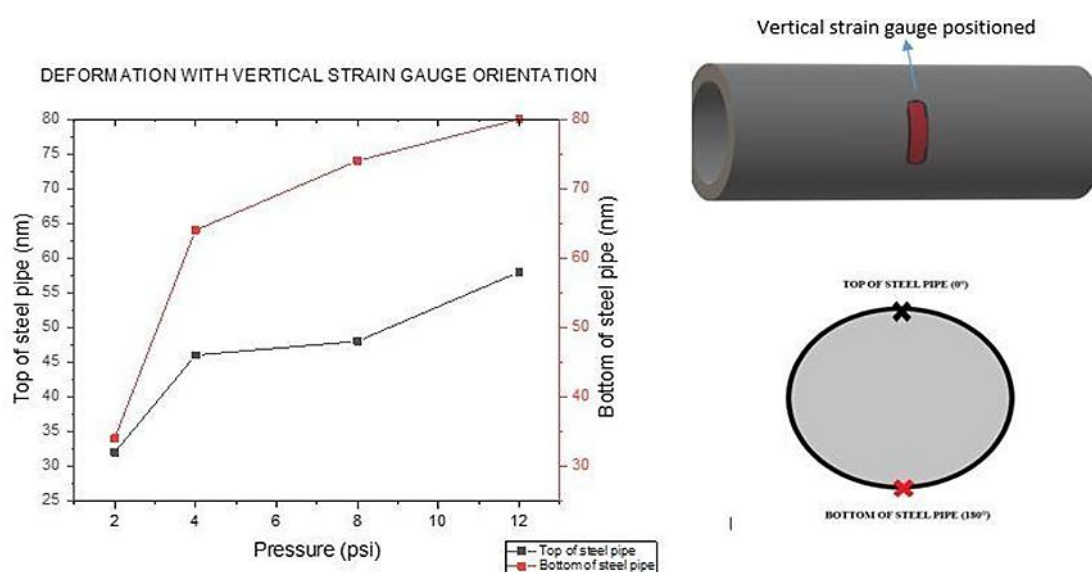
#### 3.2.1 Deformation result on steel pipe without sleeve repair

The deformation is the highest, 60 nm at the top of the steel, when the pressure is the highest at 12 psi (Figure 4). The deformation increases proportional to the pressure for both tests, on top of the steel pipe and also at the bottom of the steel pipe [15]. Deformation is lower at the bottom of the steel pipe than at the top of the steel pipe. It is proven by the data obtained at 2 psi, 8 psi and 12 psi, where the result is 30, 48, and 56 nm at the bottom of steel pipe while larger at the top of steel which are 34, 50, 60 nm. This phenomenon happens due to the flow inside the steel pipe, where the bottom of the steel pipe is at a higher flow rate than the top [16]. It shows that the top of steel deforms lesser when the pressure is increased from the initial pressure, but at the bottom of the steel, the deformation is much larger when the pressure is increased. The deformation value is the same at 4 psi because the pressure is not enough to give many changes in the deformation, where we can see significant changes in the pressure when increased to 8 psi and 12 psi. [17].



**Fig. 4.** Deformation on steel pipe without sleeve at horizontal strain gauge 0° orientation

Figure 5 shows deformation on steel pipe without sleeve repair at vertical strain gauge orientation. The graph shows the result increases, yet at an inconsistent reading in the deformation. The inconsistent increment is due to the difference in pressures. The bottom of steel's initial reading is 34 nm, while the initial reading at the top of steel is slightly lower is 32 nm. This is because the strain gauge is exerted with pressure while applying the strain gauge, which may cause a slight deformation of the strain gauge initially. The highest deformation reading for vertical orientation strain gauge is 80 nm, while for horizontal orientation is 20 nm lesser. Compared to the results of deformation obtained for the horizontally positioned strain gauge in Figure 4, the deformation is higher at the vertical orientation strain gauge. The vertical orientation strain gauge gives higher deformation because the flow inside the steel pipe is perpendicular to the flow, giving higher resistance to the strain gauge compared to when the flow is parallel. Ibrahim [18] explains that strain gauges can only detect strain in one direction, therefore multiple strain gauge orientation allows for additional measurements to be obtained, enabling a more exact evaluation of strain on the surface being measured.



**Fig. 5.** Deformation on steel pipe without sleeve repair at vertical strain gauge 90° orientation

### 3.2.2 Deformation result on steel pipe with sleeve repair

Figure 6 indicates the correlation of sleeve pipe deformation against the changes in pressure at the horizontally positioned strain gauge. The result of the graph shows that the deformation trend increases when the pressure is increased, similar to the previous graph in Figure 6. This proves that the more the pressure, the more the deformation happens on the steel pipe, either with or without sleeve repair. The graph in Figure 6 shows that the deformation is higher at the top of the steel than at the bottom. Steel pipe with SRW gives a higher deformation value at the top of the steel.

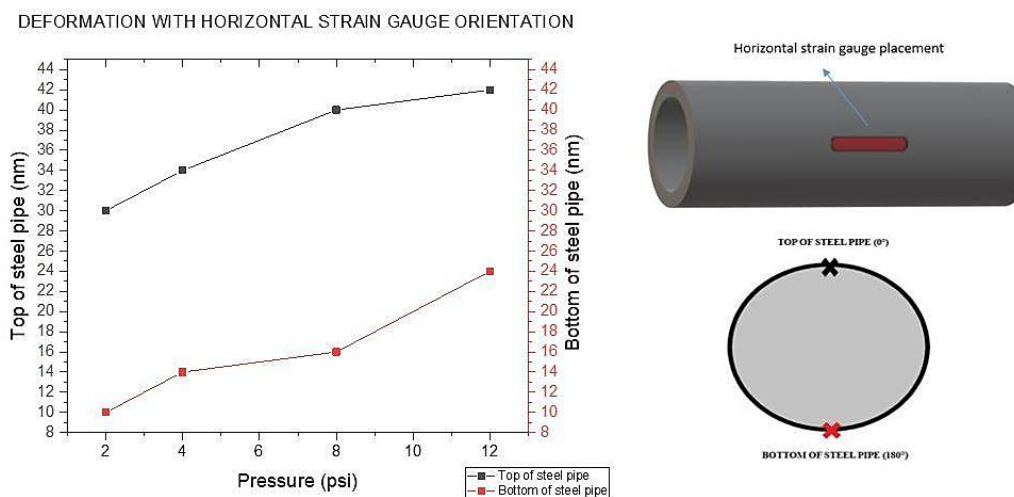


Fig. 6. Deformation with sleeve repair with horizontal orientation 0°

In Figure 7, deformation with sleeve repair with vertical orientation 90° graph is formed to analyse the deformation effect on sleeve pipe with different pressures applied. At the bottom of the steel pipe, the deformation was observed to be increasing in the high range where the initial deformation is 8 nm for 2 psi of pressure. Then the steel pipe shows an increase of deformation to 20 nm for 4 psi followed by 32 nm for 8 psi. Lastly, for deformation at the bottom of the pipe with sleeve repair, the result obtained for the last pressure of 12 psi is 34 nm, where the deformation is 2 nm increased. Overall, the trend for deformation at the bottom of steel pipe with sleeve repair shows an increasing trend because pressure increase will increase the deformation.

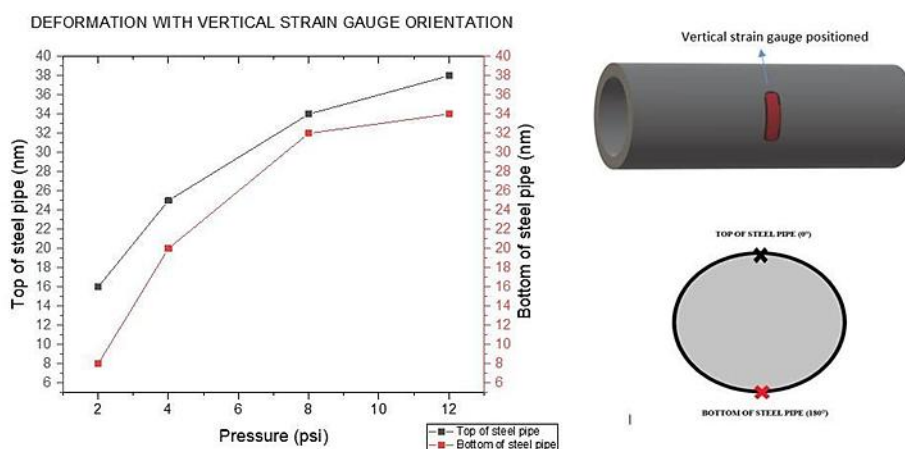


Fig. 7. Deformation with sleeve repair with the vertical orientation of 90°

The result obtained shows that the steel pipe with sleeve repair method applied has 40% much lesser strain and deformations occurrence than the steel pipe without sleeve repair. For example, for deformation in steel pipe vertically orientated, the max deformation for steel pipe with sleeve repair is only 34 nm, whereas for steel pipe without sleeve repair, it is very high at 80 nm. These results can be correlated with the study by Wan-Gon Bae on deformation that happens to steel pipes with different thicknesses and pressure [19,20].

#### 4. Conclusions

This project is carried out on a high standard carbon steel pipe which is commonly used in underground pipeline system. The study is to compare the effect of pressure stream flowing inside the pipe to the steel pipe. The test is done on steel pipe with steel SRW and without steel SRW. The study is fully on experimental approach tested using strain gauge. The strain gauge is fixed on various position and orientation to study the effects on the steel pipe such as, stress, strain and deformation. From the results obtained, the stress value is less 40% average on the steel pipe after steel SRW. In all positions and orientations of the test is shows that the stress is less on the steel sleeve welded pipe. Besides that, it can be concluded that steel pipe without steel SRW shows higher rate of 10 nm deformation in average compared to steel pipe with SRW. It is also observed that, the pressure differences effect the stress and deformation on the steel pipe. Where the graphs of the results show the stress and deformations increases when the pressure increases. The strain value also increases by 30-40 % when the pressure increases. Besides that, the steel pipe with SRW has lesser impact of strain compared to steel pipe without SRW. Hence from the result that is obtained from the experiment it can be said that steel SRW has a positive outcome on a steel pipe. Where it shows lower reading for stress, deformation and strain on the steel pipe compared to when it has no steel sleeve repair. The steel sleeve repair method can help to strengthen the steel pipe if the steel pipe has defects especially.

#### References

- [1] Vilkys, Tadas, Vitalijus Rudzinskas, Olegas Prentkovskis, Jurijus Tretjakovas, Nikolaj Višniakov, and Pavlo Maruschak. "Evaluation of failure pressure for gas pipelines with combined defects." *Metals* 8, no. 5 (2018): 346. <https://doi.org/10.3390/met8050346>
- [2] Allouti, M., C. Schmitt, and G. Pluvinage. "Assessment of a gouge and dent defect in a pipeline by a combined criterion." *Engineering Failure Analysis* 36 (2014): 1-13. <https://doi.org/10.1016/j.engfailanal.2013.10.002>
- [3] Crapps, Justin M., Xin Yue, Ronald A. Berlin, Heider A. Suarez, Petr A. Pribytkov, Brent A. Vyvial, and Jared S. Proegler. "Strain-based pipeline repair via type B sleeve." *International Journal of Offshore and Polar Engineering* 28, no. 03 (2018): 280-286. <https://doi.org/10.17736/ijope.2018.0a19>
- [4] Shuai, Yi, Xinhua Wang, Junqiang Wang, Heng-Gang Yin, and Y. Frank Cheng. "Modeling of mechanical behavior of corroded X80 steel pipeline reinforced with type-B repair sleeve." *Thin-Walled Structures* 163 (2021): 107708. <https://doi.org/10.1016/j.tws.2021.107708>
- [5] Li, Xinhong, Ziyue Han, Renren Zhang, Rouzbeh Abbassi, and Dawei Chang. "An integrated methodology to manage risk factors of aging urban oil and gas pipelines." *Journal of Loss Prevention in the Process Industries* 66 (2020): 104154. <https://doi.org/10.1016/j.jlp.2020.104154>
- [6] Lazor, Robert, L. Blair Carroll, Michael E. Bloom, and Robert F. Booth. "Modeling of pipeline repair sleeves." In *International Pipeline Conference*, vol. 36207, pp. 1991-1995. 2002. <https://doi.org/10.1115/IPC2002-27332>
- [7] Wang, Youtang, Xuyang Liu, Chengyu Li, Bin Zheng, Chunguang Wang, and Xin Tian. "Experimental study on thermal deformation of ground heat exchanger pipe." *Sustainable Energy Technologies and Assessments* 45 (2021): 101190. <https://doi.org/10.1016/j.seta.2021.101190>
- [8] Wu, Xiaonan, Hongfang Lu, and Shijuan Wu. "Stress analysis of parallel oil and gas steel pipelines in inclined tunnels." *SpringerPlus* 4, no. 1 (2015): 659. <https://doi.org/10.1186/s40064-015-1453-1>

- [9] Kanchanomai, Chaosuan, and Wiroj Limtrakarn. "Effect of residual stress on fatigue failure of carbonitrided low-carbon steel." *Journal of Materials Engineering and Performance* 17, no. 6 (2008): 879-887. <https://doi.org/10.1007/s11665-008-9212-x>
- [10] Ling, Jen Hua, Ahmad Baharuddin Abd. Rahman, Izni Syahrizal Ibrahim, and Zuhairi Abdul Hamid. "An experimental study of welded bar sleeve wall panel connection under tensile, shear, and flexural loads." *International Journal of Concrete Structures and Materials* 11, no. 3 (2017): 525-540. <https://doi.org/10.1007/s40069-017-0202-y>
- [11] Zou, Lufan, Graham A. Ferrier, Shahraam Afshar V, Qinrong Yu, Liang Chen, and Xiaoyi Bao. "Distributed Brillouin scattering sensor for discrimination of wall-thinning defects in steel pipe under internal pressure." *Applied optics* 43, no. 7 (2004): 1583-1588. <https://doi.org/10.1364/AO.43.001583>
- [12] Crapps, Justin M., Xin Yue, Ronald A. Berlin, Heider A. Suarez, Petr A. Pribytkov, Brent A. Vyvial, and Jared S. Proegler. "Strain-based pipeline repair via type B sleeve." *International Journal of Offshore and Polar Engineering* 28, no. 03 (2018): 280-286. <https://doi.org/10.17736/ijope.2018.oa19>
- [13] Paterson, M. S. "Effect of pressure on stress-strain properties of materials." *Geophysical Journal International* 14, no. 1-4 (1967): 13-17. <https://doi.org/10.1111/j.1365-246X.1967.tb06217.x>
- [14] Arifin, Hanis Hazirah, Libriati Zardasti, Kar Sing Lim, Norhazilan Md Noor, Nordin Yahaya, Ain Naadia Mazlan, and Abdul Rahman Mohd Sam. "Stress distribution analysis of composite repair with Carbon Nanotubes reinforced putty for damaged steel pipeline." *International Journal of Pressure Vessels and Piping* 194 (2021): 104537. <https://doi.org/10.1016/j.ijpvp.2021.104537>
- [15] Pleşcan, Costel, Mariana D. Stanciu, and Matyas Szasz. "The effect of internal pressure on radial strain of steel pipe subjected to monotonic and cyclic loading." *Materials* 12, no. 18 (2019): 2849. <https://doi.org/10.3390/ma12182849>
- [16] Lasebikan, B. A., and A. R. Akisanya. "Burst pressure of super duplex stainless steel pipes subject to combined axial tension, internal pressure and elevated temperature." *International Journal of Pressure Vessels and Piping* 119 (2014): 62-68. <https://doi.org/10.1016/j.ijpvp.2014.03.001>
- [17] Chapetti, Mirco Daniel, J. L. Otegui, Carlos Manfredi, and C. F. Martins. "Full scale experimental analysis of stress states in sleeve repairs of gas pipelines." *International Journal of Pressure Vessels and Piping* 78, no. 5 (2001): 379-387. [https://doi.org/10.1016/S0308-0161\(00\)00063-6](https://doi.org/10.1016/S0308-0161(00)00063-6)
- [18] Ibrahim, R. A. "Overview of mechanics of pipes conveying fluids—Part I: Fundamental studies." (2010): 034001. <https://doi.org/10.1115/1.4001271>
- [19] Bae, Wan-Gon, Kyong-Ho Chang, and Chin-Hyung Lee. "Progressive inelastic deformation of a girth-welded stainless steel pipe under internal pressure and cyclic bending." *Ocean Engineering* 128 (2016): 81-93. <https://doi.org/10.1016/j.oceaneng.2016.10.027>
- [20] Paterson, M. S. "Effect of pressure on stress-strain properties of materials." *Geophysical Journal International* 14, no. 1-4 (1967): 13-17. <https://doi.org/10.1111/j.1365-246X.1967.tb06217.x>