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Research for KGS FS551 Amendment Using Abroad Code and Structure Simulation

Byung-Ik Kang[*,#], Byung-Gi Kim[*], Byung-Duk Kim[*]
[*]Korea Gas Safety Corporation(KGS)

해외규격과 구조해석을 이용한 KGS FS551 개정안 연구

강병익[*,#], 김병기[*], 김병덕[*]
[*]한국가스안전공사

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ABSTRACT

According to KGS FS551, the safety of an exposure pipe system should be calculated quantitatively by calculating the stress of exposed piping for thermal expansion. However, many pipe system designs and installation sites are not equipped for this. Therefore, KGS FS551 suggested the use of safe gas by presenting the recommended pipe shape. The shapes of various pipe systems have been derived. However, the recommended shape could not be an absolute evaluation standard. Furthermore, the ongoing debate over standards between a plumbing installer and an inspector is an obstacle to the efficient and safe use of gas. Therefore, the correct pipe system evaluation method is examined in this study, and the safety of the existing exposed pipe system is verified.

Keywords : Exposure Pipe System(노출 배관 시스템), KGS FS551, Durability Safety Assessement(내구 안전성 평가), Structure Simulation(구조 해석)

- Symbol Description -

S_L : Axial stress in pipe
S_H : Radial stress in pipe
σ_e : Equivalent stress for thermal load
σ_A : Fatigue strength for thermal load

1. Introduction

Gas is treated as an energy source with a relatively low supply price and abundant supply, which is highly available. As a result, gas has been used for various applications. For this gas consumption activity, piping is mainly used for gas transfer from the gas reservoir to the gas consumer. However, since gas has wide mobility and high explosiveness, high durability reliability of related products is required. In particular, unlike buried pipes, exposure piping is directly exposed to the outside air, which can lead to serious social and economic problems. Therefore, Korea Gas Safety Corporation recommends the evaluation method of exposure piping

Corresponding Author : byoungik5@gmail.com
Tel: +82-10-9331-6097, Fax: +82-43-750-1948

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and the shape of exposure piping system in KGS FS 551 contents.

However, the method of evaluating the above-mentioned exposed piping has a limitation in safely evaluating the entire piping system by extracting only a part of the high authority ASME standard. In addition, the shape of the exposure piping system recommended in the existing KGS FS 551 standard has been consistently incapable of guaranteeing the shape of various exposure piping systems currently being developed. In order to clearly solve the above-mentioned problem, it is certain that the safety is evaluated by clearly defining the load, material and shape of the piping system. However, considering the current situation and level of designing and constructing exposed piping, there are many negative views on enactment of relevant laws and securing manpower in order to apply the above-mentioned evaluation.

Therefore, this study presents the accurate evaluation method of the piping system, and confirms the durability safety through the structural simulation of the shapes of the piping system where the KGS FS551 can not guarantee the safety and causes many conflicts between the installer and the inspector. The ASME code of the Mother Standard of the piping standard was used to accurately evaluate the piping system. For the piping system in question, the durability safety was verified qualitatively by comparing the structural simulation results of the piping system securing high safety factor by existing experience and the structural simulation result of the piping system having question.

2. Piping System Features

Reliable storage and transport is the basis for safe gas use. As a representative facility for this gas storage and transportation, vessels and piping can be considered. This situation has led many gas experts to be cautious in assessing the durability of vessels and piping. However, As shown in Fig. 1, the piping is based on a complicated shape unlike the shape of the vessel. Therefore, it is difficult to apply the evaluation expressions expressed in the standard directly to the overall shape of the piping system. This content is also available through the ASME code, which are globally authoritative. In the case of vessels, stress and thickness are expressed in a relatively simple form[1]. This is because the shape of the vessel is constant, the flow of the load is relatively simple, and the flow is predictable. On the other hand, in the case of piping, there is no numerical formula for evaluating the overall shape due to the complicated shape and the load flow caused by it, and instead, a method for evaluating the partial shape based on the basic principal stress theory and von-Mises stress theory[2,3]. In addition, in the durability safety evaluation, since the magnitude and the influence of the strain energy from the low stiffness of the piping system are large, ASME is divided into constrained piping system of surrounding displacement and unconstrained piping system of surrounding displace[2,3].

The AMSE method for evaluating according to the peripheral displacement is shown in Fig. 2. Fig. 2, ASME differentiates whether stress due to temperature (S_T) is considered depending on the constraint of peripheral displacement. It can be seen from the ASME pipe evaluation method that the piping should confirm the deformation and displacement of the entire piping system in order to derive the local stress. As a result, even if it is the ASME standard which is Mother Standard of pipe evaluation, it means that it is difficult to evaluate the durability safety of the entire piping system only by numerical calculation.

The durability evaluation of the piping system described in the previous paragraph is compared with the durability evaluation of other general mechanical parts as shown in Fig. 3. Usually, in the case of mechanical parts, the internal rigidity is supported by

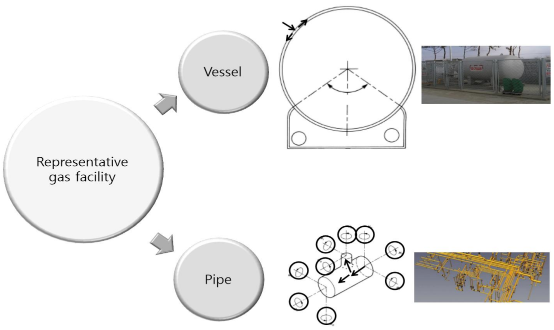


Fig. 1 Comparison of characteristics of vessel and pipe

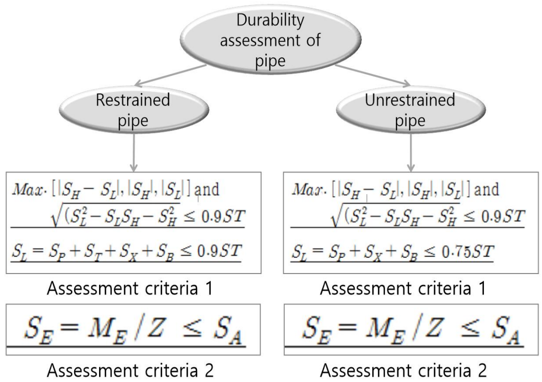


Fig. 2 Durability assessment method in ASME

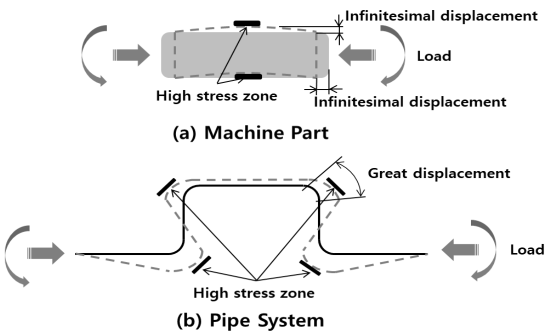


Fig. 3 Comparison of machine part and pipe system

the high rigidity of the mechanical parts, so that the overall shape of the mechanical parts is less deformed and most of them are consumed by the stress generation. In this way, if the overall shape deformation is small, the assumption and simplification can be used for durability evaluation. On the other hand, the low stiffness of the piping system induces large deformation as a whole when the load acts on the piping system. This means that much of the energy is consumed by the overall shape change of the piping system before stress builds up inside the piping. Also, the low stiffness of the pipe during the overall shape change of the piping system due to the load can cause problems such as buckling due to excessive displacement. For this reason, in order to accurately evaluate the durability of the piping system, it is necessary to select an appropriate method for predicting the overall displacement prediction before stress analysis.

However, if welds to the vessel or piping are a problem, the durability assessment method will be accompanied by a rather complicated method, unlike the previous explanation. This is because, in the case of welding, the energy input is needed to narrow the distance between the two surfaces to within the atomic distance[4] and the energy input affects the crystal structure and particle size of the base material. The AWS[5] or IIW[6] standard can be used to evaluate these welds. AWS can evaluate welds using nominal stresses, but welds can be evaluated using IIW if nominal stresses are not available, depending on the shape of the welds and base metal.

3. How to Evaluate the Durability for Piping System

In general, four methods of code, measurement, experiment and simulation can be considered as methods for evaluating durability safety. These methods are as follows.

In the case of the code, the reliability of the evaluation result can be secured based on the authority of the code, but it is difficult to derive the stress of the dangerous part based on the overall deformation. In addition, since the code formula implies the assumption and the simplification, the accuracy of the resultant value is deteriorated with respect to a complicated shape.

In the case of measurement, partial evaluation is possible, not the overall evaluation as in the code. In addition, the low pressure used in the gas piping and the use environment of the buried piping can deteriorate the S / N ratio[7], which is one of the reliability measures of the measurement results. There is a risk that the position of the high stress portion, which is the standard of the durability safety evaluation, is selected depending on the experience only.

In the case of experiments, it is a relatively accurate evaluation method for confirming the local specifications such as the fracture toughness of the piping, but it is difficult to evaluate the piping system actually used. The reason for this is that even if the test subject is divided into a buried pipe and an exposed pipe, the pipe length of the test object exceeds several hundred meters. In addition, even if the large piping system is constituted, a constant temperature system of piping system size must be constructed in order to allow the temperature to be one of the main loads of the piping system. Therefore, experiments for piping system evaluation can be a great economic waste. Furthermore, considering the manufacturing period of the design and installation of the piping system, it is considered that there are not enough time to carry out the long experiment time and improve design.

Finally, in case of simulation unlike the three methods described above, the stress of the hazardous part can be obtained along with the overall deformation of the piping system. However, there is a disadvantage that it is difficult to consider the scattering of the actual product in the simulation. However, the piping system is predicted to have low stiffness and high deformation as a whole as mentioned above, and it can be confirmed that there is a design margin. In addition, we can present solutions based on quality documents such as WPS and PQR for the scatter problem, which has been presented as a disadvantage of the above simulation. Therefore, many companies and research organizations in Korea and abroad are evaluating the durability of piping systems using simulation[8]. Fig. 4 shows the previous contents.

In order to evaluate the piping system by the simulation, it is necessary to define the material, shape, and load as shown in Fig. 5[9]. The material and shape of the piping system are determined by the design, and the loads vary depending on the usage environment of the piping system. The basic types of various loads acting on the piping system are shown in Fig. 6. After the material, shape, and load for piping system simulation are defined, reducing modeling is needed to improve the efficiency of simulation. Boundaries of buried and exposed piping can be used to reduce modeling. If boundary conditions are set at the boundary, the efficiency of piping system simulation can be improved. A method widely used for reasonably capturing the boundary conditions is Peng's virtual fixed point[10] and the American Lifeline Alliance method as shown in Fig. 7.

Based on the above modeling, there are two methods for evaluating the stress, which is the durability safety evaluation standard. First, we evaluate

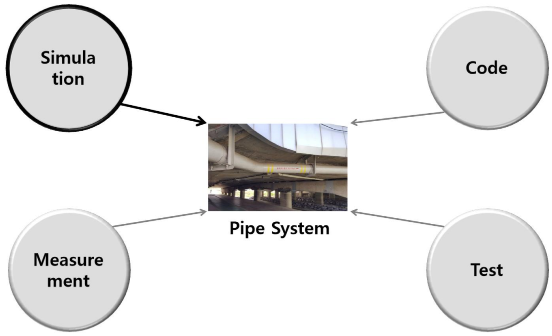


Fig. 4 Methods for pipe system durability assessment

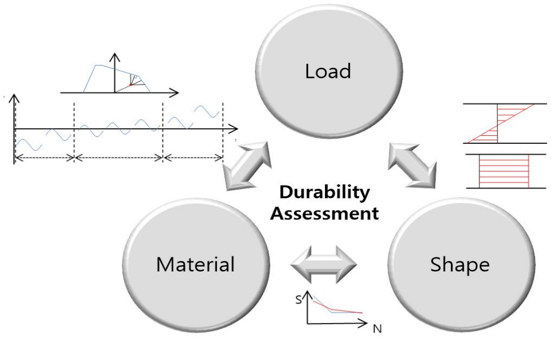


Fig. 5 Key factors for durability assessment

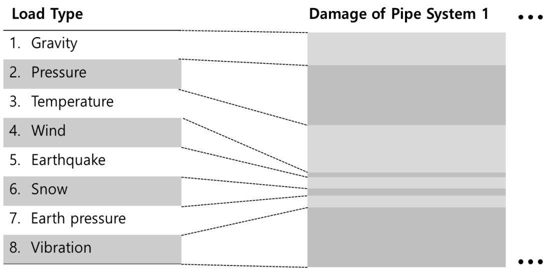


Fig. 6 Damage of pipe system with load type

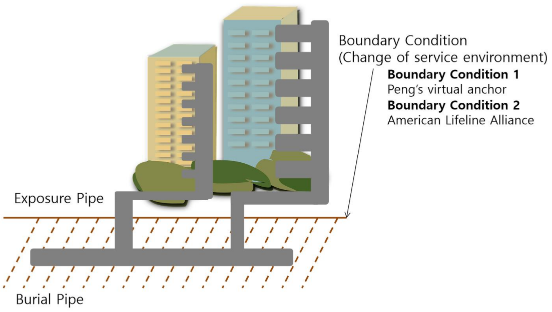


Fig. 7 Boundary conditions in simulation

the stresses derived from the ASME code formulas in Eqs. (1) - (7). This is an evaluation method that is specific to the piping system and can reduce the disagreements that may arise between the expected parties in the authority of the code. Second, the durability safety evaluation of the piping system is carried out using the fatigue Miner rule[11]. This can be evaluated individually for various loads, and as shown in Fig. 8, it is possible to change the S-N curve, which is an evaluation standard, to suit the environment of use, so that an effective durability safety evaluation is possible. With this advantage, a second evaluation method is widely used in industry.

when pipe is restrained

$$|S_H - S_L| \le 0.9ST \quad (1)$$

$$|S_H| \le 0.9ST \quad (2)$$

$$|S_H| \le 0.9ST \quad (3)$$

$$\sqrt{(S_L^2 - S_L S_H + S_H^2)} \le 0.9ST \quad (4)$$

$$S_L = S_P + S_T + S_X + S_B \le 0.9ST \quad (5)$$

$$S_E = M_E / Z \le S_A \quad (6)$$

when pipe is unrestrained

$$|S_H - S_L| \le 0.9ST \quad (1)$$

$$|S_H| \le 0.9ST \quad (2)$$

$$|S_H| \le 0.9ST \quad (3)$$

$$\sqrt{(S_L^2 - S_L S_H + S_H^2)} \le 0.9ST \quad (4)$$

$$S_L = S_P + S_X + S_B \le 0.75ST \quad (7)$$

$$S_E = M_E / Z \le S_A \quad (6)$$

However, both of the above methods have a disadvantage in that it is difficult to accurately derive the influence of all the loads on the stress value. For example, if you look at the ASME formula, it is difficult to get an accurate assessment if the stress contributions of S_X and S_B are missing from the load such as wind load. The evaluation using the Miner rule has the same disadvantages. In order to solve this problem, it is possible to secure safety against various loads that are not evaluated by imposing a safety factor higher than a certain value after evaluation based on the main load. In this case, it may be questioned about the safety factor setting, but if it is set based on the safety factor of the piping system which has survived the existing lifetime, it will be possible to secure the safety of the piping system and the consensus of the related persons. The

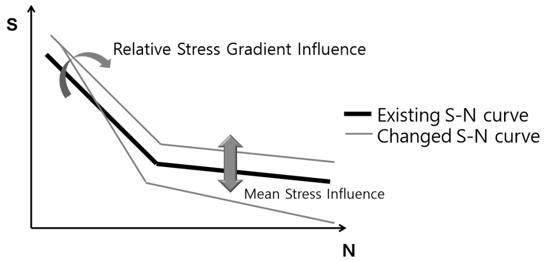


Fig. 8 Change of S-N curve for environment[12]

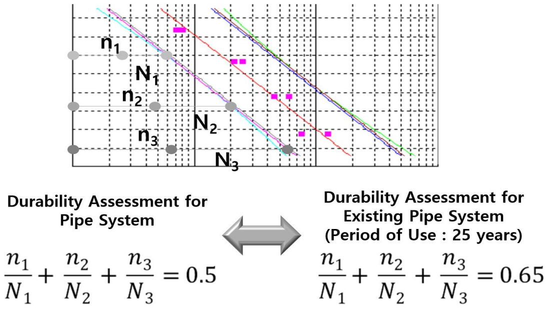


Fig. 9 Durability assessment for piping

contents of the above description are shown in Fig. 8 and Eq. (8).

$$D=\frac{n_1}{N_1}+\frac{n_2}{N_2}+\frac{n_3}{N_3}...=\sum\frac{n_i}{N_i} \tag{8}$$

4. KGS FS551 Amendment

KGS FS551 "General Facilities of City Gas Plant and Facilities Outside of Supply Pipes • Technology • Inspection • Criteria for Precision Safety Diagnosis" is a standard describing inspection of piping for safe gas use. Therefore, there is also a description of the durability evaluation method of the pipe, which is the same as the characteristics of the pipe described above and the durability evaluation method corresponding thereto. The contents are concentrated on the 2.5.6 "Absorption Measures of Piping System for Temperature" and Appendix B "Absorption Measures of Urban Gas Exposed Pipes for Temperature".

First of all, the contents of 2.5.6, "Absorption Measures of Piping System for Temperature", are as follows. 2.5.6 The content is evaluated as the only durability evaluation item of the piping system. At this time, the evaluation items came from ASME contents. In this case, the evaluation criterion is a comparison of the equation (9) for the plane stress state of von-Mises caused by the thermal load and the fatigue strength equation (10) shown in ASME. However, these evaluation methods are only part of the piping system evaluation criteria described earlier and in ASME. Therefore, it is necessary to match this with the authoritative evaluation criteria of ASME. For this, an amendment was derived from the evaluation method of Eqs. (1) to (7), which is the content of Fig. 2.

$$\sigma_e=\sqrt{\sigma_b^2+4\sigma_t^2} \tag{9}$$

$$\sigma_A=f(1.25\sigma_C+0.25\sigma_n) \tag{10}$$

The following is Appendix B, "Absorption Measures of Urban Gas Exposed Pipes for Temperature". Appendix B presents the shape of a safe piping system. However, unlike the piping system form inserted in Annex B, various buildings are presently present and the shape of the piping system is variously manufactured. However, it is difficult to evaluate the durability of the piping system by using the simulation of different shapes. In order to securely specify the piping system shape, Fig. 10 and Eq. (11) should be used. However, looking at all of these requires a lot of time consumption, as shown in Fig. 10, and the same process should be followed if other shapes appear. However, as mentioned above, many piping system design and manufacturing sites do not have practical preparation to use the above method.

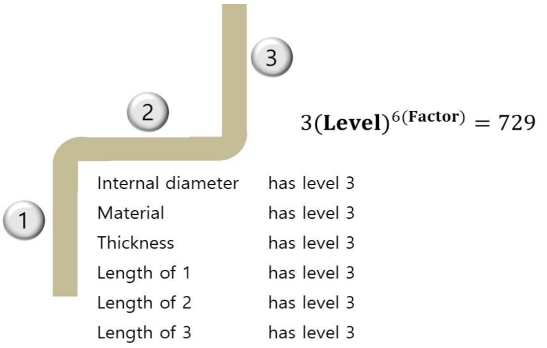


Fig. 10 Number for suggestion of pipe system

$$L^F = Number\,of\,Consideration \tag{11}$$

Therefore, we obtained the shape of piping system with many civil complaints and compared the safety of the piping system that secured the safety by merely evaluating the thermal stress for several decades. The standardized piping system was defined as ensuring sufficient safety for different loads with only thermal stress assessment and lifetime safety during the minimum service life. Therefore, structural simulation (Table 1 ~ 3) was carried out according to the shape and thickness of the piping system in which complaints mainly occur, and compared with the shape of the piping system as a reference (Table 4). For the simulation conditions, contact analysis was performed on the guide part to see the accurate stress distribution, and the top shape of the same formed piping system was excluded for the qualitative comparison of the simulation results. The results are shown in Fig. 11-14. In conclusion, the comparison of the safety of existing piping system by radius shows Fig. 15 to 17 can be confirmed. As a result, some of the shapes of Table 1 and 2 can be used in comparison with the existing safe shape, but it is found that the shape of Table 3 is difficult to use.

Table 1 Structure simulation modeling set 1

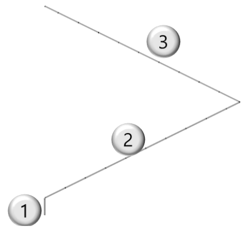
	Nominal Diameter	1 (mm)	2 (mm)	3 (mm)
Case1_1	100A	2,000	29,000	29,000
Case1_2	100A	2,000	16,000	16,000
Case1_3	80A	2,000	29,000	29,000
Case1_4	80A	2,000	16,000	16,000
Case1_5	50A	2,000	29,000	29,000
Case1_6	50A	2,000	16,000	16,000
Typical Shape				

Table 2 Structure simulation modeling set 2

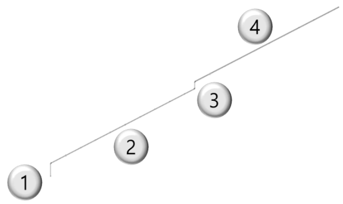
	Nominal Diameter	1 (mm)	2 (mm)	3 (mm)	4 (mm)
Case2_1	100A	2,000	29,000	1,000	29,000
Case2_2	100A	2,000	16,000	1,000	16,000
Case2_3	80A	2,000	29,000	500	29,000
Case2_4	80A	2,000	16,000	500	16,000
Case2_5	50A	2,000	29,000	500	29,000
Case2_6	50A	2,000	16,000	500	16,000
Typical Shape					

Table 3 Structure simulation modeling set 3

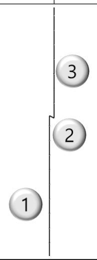
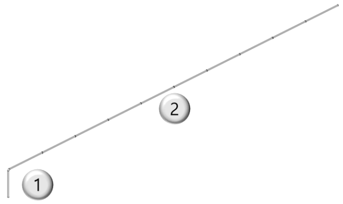
	Nominal Diameter	1 (mm)	2 (mm)	3 (mm)
Case3_1	100A	29,000	1,000	29,000
Case3_2	100A	2,000	1,000	29,000
Case3_3	80A	29,000	500	29,000
Case3_4	80A	2,000	500	29,000
Case3_5	50A	29,000	500	29,000
Case3_6	50A	2,000	500	29,000
Typical Shape				

Table 4 Structure simulation modeling set 4

	Nominal Diameter	① (mm)	② (mm)
Case4_1	100A	2,000	30,000
Case4_2	80A	2,000	30,000
Case4_3	50A	2,000	30,000
Typical Shape			

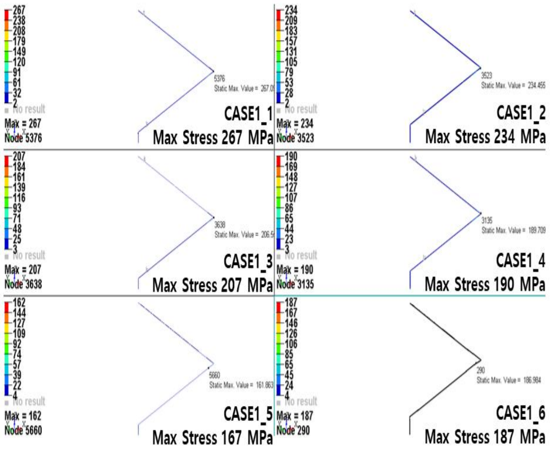


Fig. 11 Results of Table 1

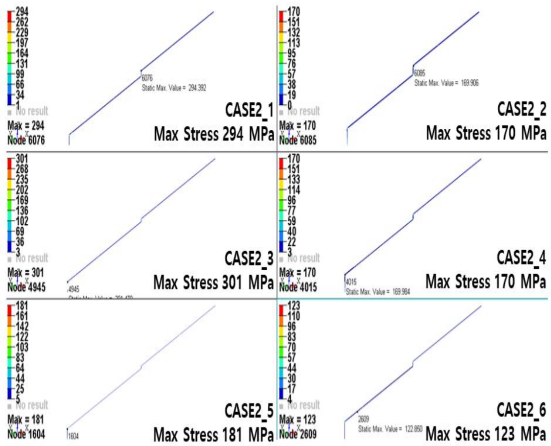


Fig. 12 Results of Table 2

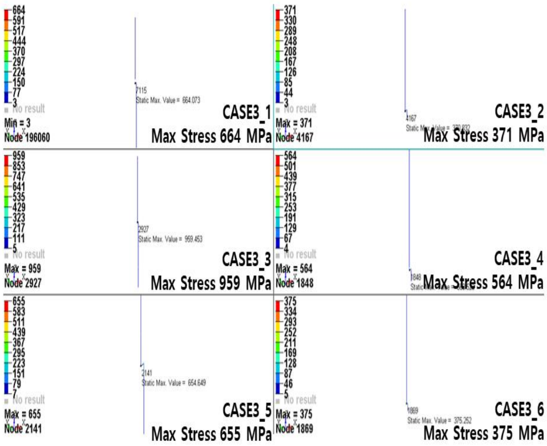


Fig. 13 Results of Table 3

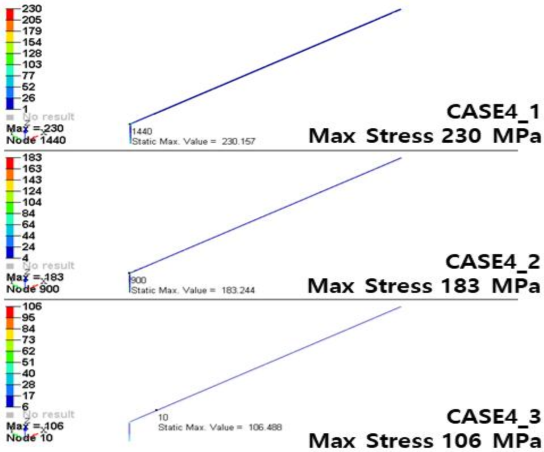


Fig. 14 Results of Table 4

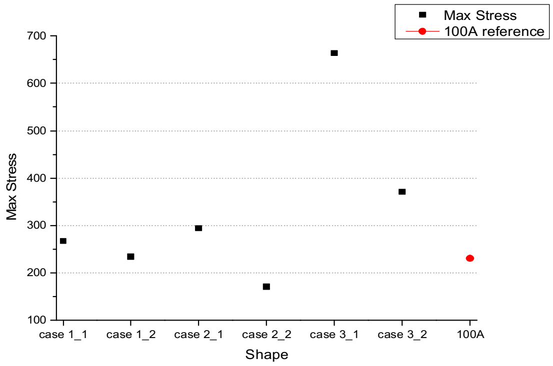


Fig. 15 Comparison results in 100A

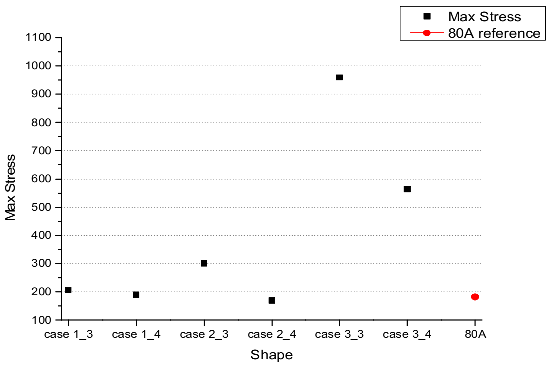


Fig. 16 Comparison results in 80A

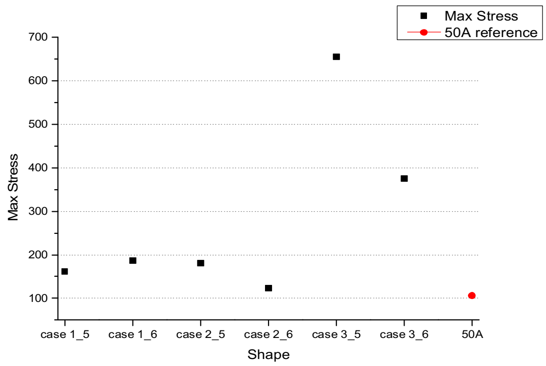


Fig. 17 Comparison results in 50A

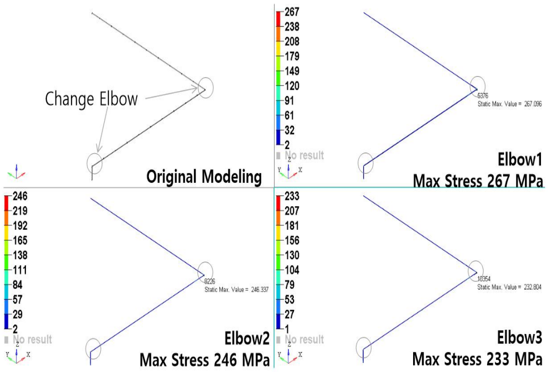


Fig. 18 Results according to elbow types

However, the above contents can not be an absolute standard for piping system design. If the safety of the piping system is ensured by the method of "3. How to evaluate the durability for Piping System", it can be judged that the safety of the piping system is ensured like the shapes modified in Appendix B of KGS FS551. It can be seen that the maximum stress value and distribution are different even if only the uniform curvature used for the qualitative comparison during the structural simulation is changed (Fig. 18).

5. Conclusion

Piping is an important hardware for sending and receiving gas. Also, considering the current energy development situation, the importance of gas piping is expected to increase. However, in case of piping, it is difficult to evaluate the accurate durability safety due to the complicated shape unlike the vessel. In addition, the increasingly complicated shape of the building and the shape of the piping system accordingly have many difficulties in evaluating durability with the existing KGS FS 551 alone.

In this study, reliability of the existing KGS FS551 piping evaluation method was secured by using the ASME international code which is Mother Standard of the piping. In addition, the shape of the piping system, which was not guaranteed by the existing code, is compared with the shape and durability of the pipe system whose safety has been confirmed empirically. Based on the results of the study, it is expected that the proposed revision of KGS FS551 will mitigate the conflicts among gas pipeline related persons based on the clear criteria and present the efficient and safe use of gas to the people.

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