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Stress Analysis for New Gasketless Flange and Superseal

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ABSTRACT

This paper deals with a new seal system between two flanges without using gaskets. The system includes a groove and an annular lip that is held by one of the flange with its highest point in contact with the other flange to form a seal line when the flanges are assembled. The condition whether the system leaks or not depends on the shape and dimension of a thinned area with the annular lip deformed during the contact. In this study several gasketless flanges are prepared with varying the fundamental dimensions of the deformed area to investigate the condition through an experiment and FEM analysis. The analysis indicates that the conditions can be expressed in terms of the maximum contact stress and the plastic zone size when the flanges are assembled.

1. INTRODUCTION

Between any pipe flanges it is necessary to choose a suitable gasket depending on the kind of fluids with their pressure and temperature to obtain good seal systems. However, generally the sealing performance of gaskets deteriorates in several years, and, therefore, the maintenance to find a leak and to renew the gasket has been required. In this paper a new seal system between two flanges without using gaskets has been treated. Figure 1 shows the system that includes a groove and an annular lip that is held by one of the flange with its highest point in contact with the other flange to form a seal line when the flanges are assembled. Figure 2 also shows a similar system called ÒsupersealÓ, which is inserted between the flanges currently used. In this study several gasketless flanges and superseals are prepared with varying fundamental dimensions of the deformed area to investigate the sealing mechanism through an experiment and FEM analysis.

2. EXPERIMENTAL METHOD

Figure 2 indicates dimensions of models used in this study. By comparing the results of the model A and model B, we may find how the groove works. From the results of models B and C we may find a suitable dimension of the thickness h. From the results of the models C and D we may find a suitable dimension of the groove depth. The material used is 0.25 percent carbon steel S25C (JIS). The maximum surface roughness at the annular lip is Rmax=4 (JIS) and the maximum surface roughness of the other flange is Rmax=80. After the flanges are clamped by bolts of

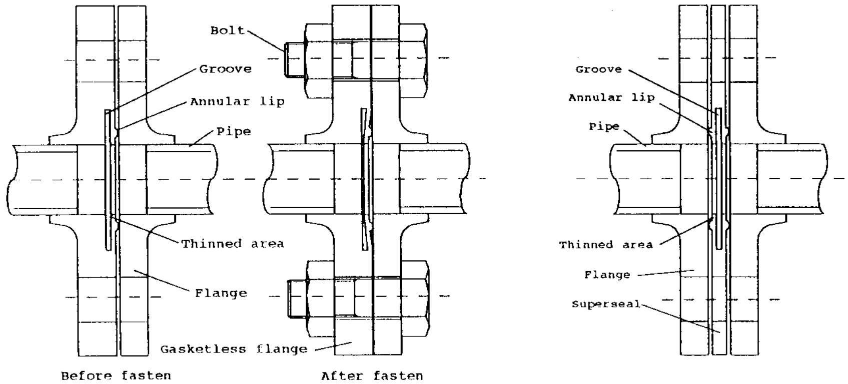
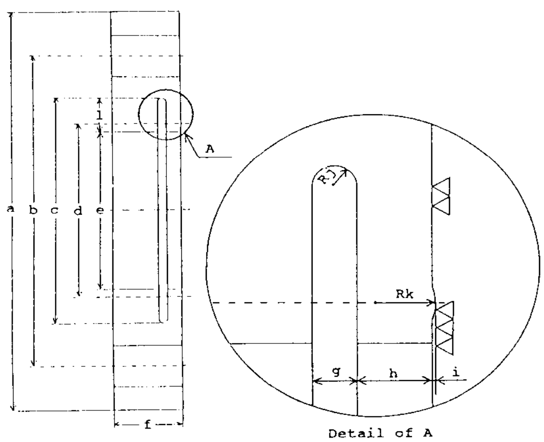


Fig. 1. Gasketless flange and superseal

M16, an internal pressure 4.9MPa is applied to these models by water-hydraulic pump. The results of sealing performance are shown in the right end in Table 1. The symbol ○ means there has been no leak for model B, △ means there is no leak in the first trial but leaks in the second trial after released and clamped again for model A, and ● means there is leak in the first trial for model C. Through the experiment it is found that the sealing performance depends on the shape and dimension of a thinned area involving the annular lip, which is deformed during the contact.



	model	c	d	f	g	h	l	experimental results
no groove	A	-	67	24	0	∞	-	△
h=5mm	B	87	67	24	3	5	13	○
h=3mm	C	87	67	22	3	3	13	●
l=8mm	D	77	67	22	3	3	8	-

○: nonleak △: First nonleak, next leak ●: leak

Fig. 2. Dimension of experiment model (mm)

3. ANALYTICAL METHOD

The FEM analysis is applied using 4 node axisymmetric element. The total number of element is 2624~2961 and the total number of node is 2816~3173. The clamping force is estimated about 98kN from the torque applied to the bolts and approximated by axisymmetric uniform distribution. The stress-strain relation is indicated in Fig. 3. Figure 3 shows the stress-strain relation with Young's modules E=20580MPa, Poisson's ratio ν =0.3, the yielding stress is 255MPa.

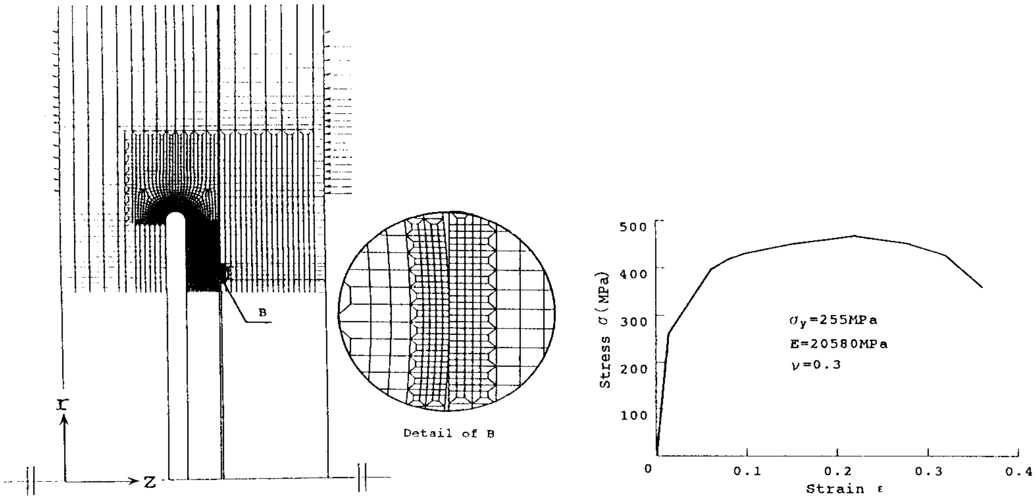


Fig. 3. Finite element mesh and material property

4. RESULTS AND DISCUSSION

Figure 4 shows Mises equivalent stress for (a) gasketless flange and (b) superseal. Since Fig. 4 (a) and Fig. 4 (b) are not very different, the results of superseals can be regarded as the ones of gasketless flanges. Figure 5 indicates the effect of internal pressure 4.9MPa applied to the model B. The plastic zone size around the root of groove in Fig.5(b) is smaller than the one in Fig.5(a). Therefore large internal pressure may be useful for sealing performance because of the small plastic zone size. Figure 6 shows the relation between the clamping force and contact length. For models B and C, if the clamping force is large enough the contact length becomes independent of the force.

Figures 7-9 show Mises equivalent stress. The maximum stresses are almost equal for models A, B, C, that is, $\sigma_{eq\,max}$ ≒286MPa.. On the other hand, the maximum stresses in the z-direction $\sigma_{z\,max}$ ≒-1200MPa for models A and B, but $\sigma_{z\,max}$ ≒-900MPa for model C, which is smaller by about 25 percent. It may be concluded that the reason why model C leaks at the small value of $\sigma_{z\,max}$. The FEM results also indicate that for model A the plastic zone size around the contact region is larger. Because of this large plastic deformation, model A seems to leak in the second trial after released and clamped again although there is no leak in the first trial. Finally, a suitable groove depth is considered because models A, B, C have a constant groove depth, l =13mm. Figure 10 shows the results for model D, where l =8mm and h = 3mm. By reducing the depth the maximum stresses in the z-direction $\sigma_{z\,max}$ ≒-1300MPa with a suitable plastic zone size. However., around the root of the groove the plastic zone prevails all over the section, and therefore, the sealing performance seems worse in the second trial. The FEM analysis indicates that the conditions whether the system has a leak or not can be controlled by the maximum contact stress with the plastic zone size when the flanges are assembled. It may be concluded that the dimensions of model B is suitable because of large contact stress and suitable plastic zone size.

5. CONCLUSION

Generally the sealing performance of gaskets between any pipe flanges deteriorates in several

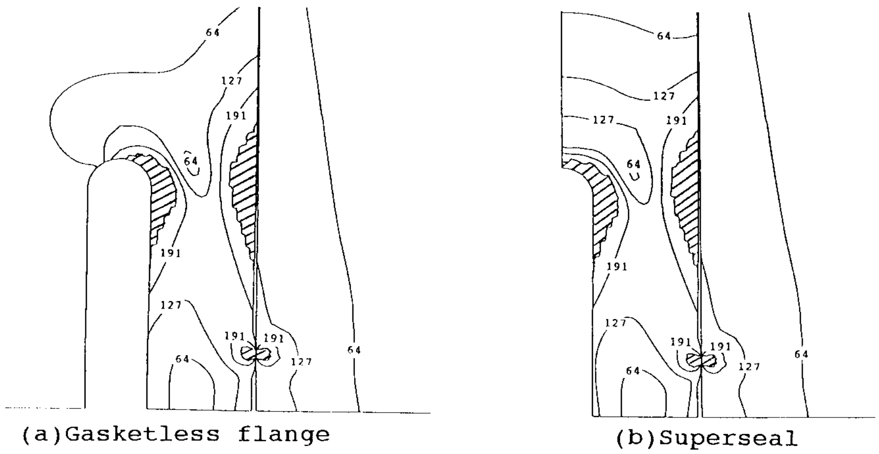


Fig.4. Mises equivalent stress σ_{eq} (MPa) [hatched] plastic zone

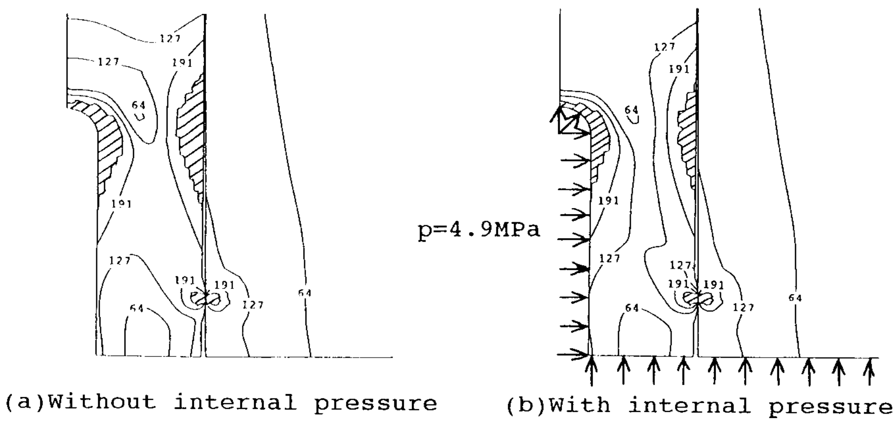


Fig.5. Mises equivalent stress σ_{eq} (MPa) [hatched] plastic zone

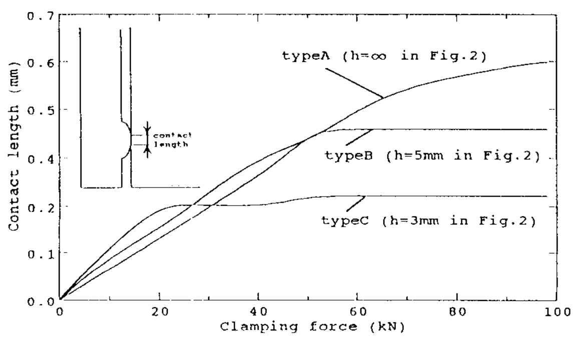


Fig.6.Contact length vs. Clamping force relation

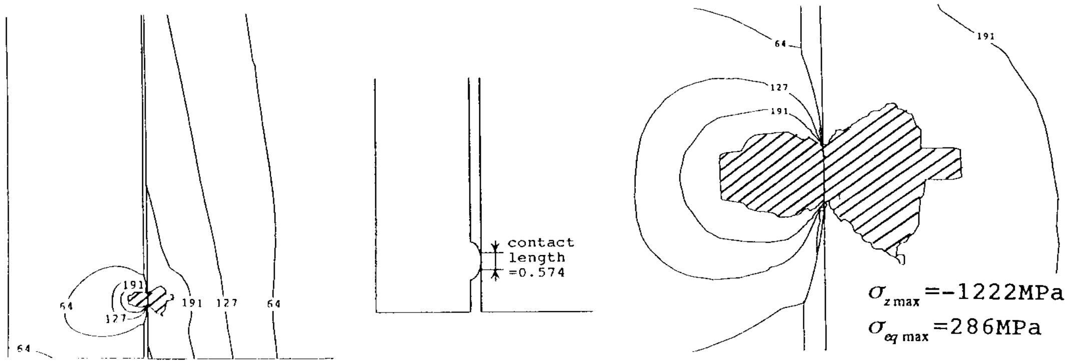


Fig.7. Equivalent stress σ_{eq} for model A (no groove, h=∞ in Fig.2) plastic zone

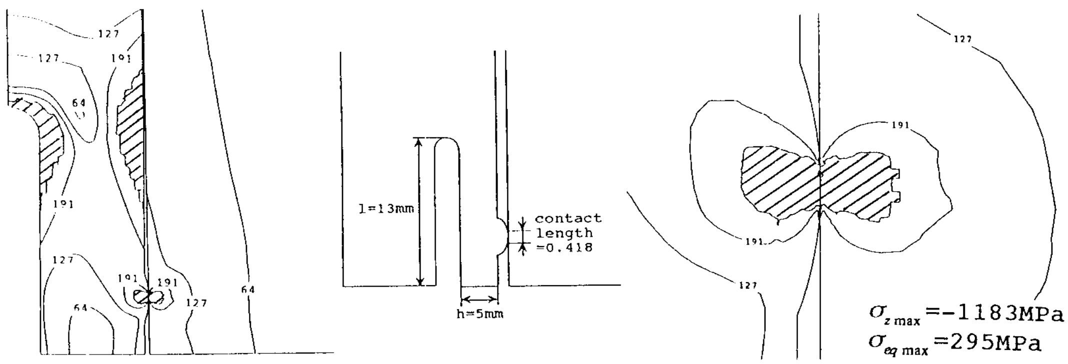


Fig.8. Equivalent stress σ_{eq} for model B (h=5mm in Fig.2) plastic zone

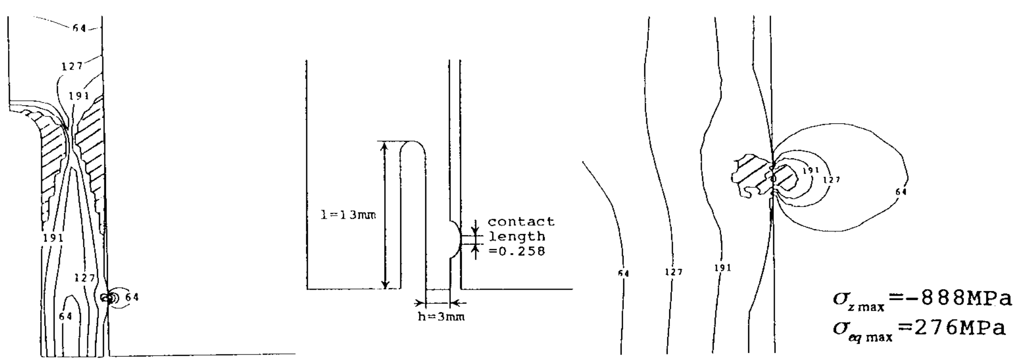


Fig.9. Equivalent stress σ_{eq} for model C (h=3mm in Fig.2) plastic zone

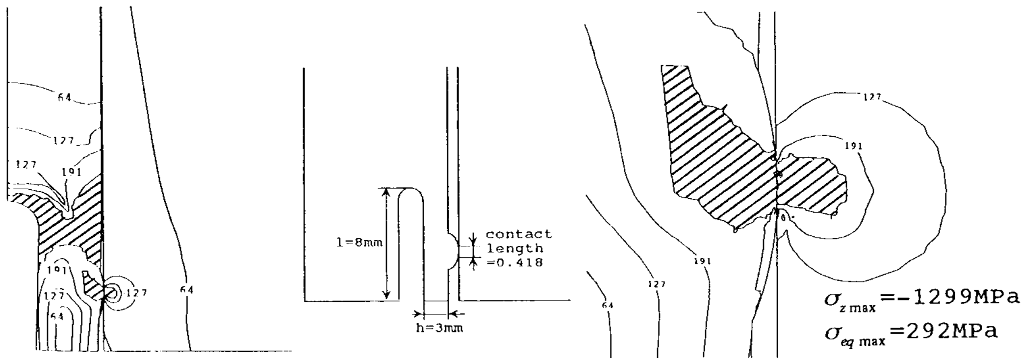


Fig.10. Equivalent stress σ_{eq} for model D (l=8mm in Fig.2) plastic zone

years, and, therefore, the maintenance to find a leak and to renew the gasket has been required. In this paper a new seal system without using gaskets has been considered. In this study several gasketless flanges are prepared with varying fundamental dimensions of the deformed area to form a seal line during contact in order to investigate the sealing mechanism. Through an experiment and FEM analysis the following conclusions can be made.

(1) Three experimental models A, B, C are investigated. For model A, which has no groove, there is no leak in the first trial but leaks in the second trial after released and clamped again. There has been no leak for model B, whose thickness of a thinned area h = 5mm. There is a leak from the first trial for model C, where h=3mm. Through the experiment it is found that the sealing performance depends on the shape and dimension of a thinned area involving the annular lip, which is deformed during the contact.

(2) FEM analysis indicates that the maximum stress at the contact zone $\sigma_{z\,max} \fallingdotseq$ -1200MPa with a suitable plastic zone size is necessary for good sealing performance. For example, model C leaks because of the small value of $\sigma_{z\,max} \fallingdotseq$ -900MPa, and model A leaks in the second trial due to the large plastic deformation at the contact region. It may be concluded that the dimensions of model B is suitable because of large contact stress and suitable plastic zone size.

(3) The experiment and FEM analysis show the internal pressure is useful for sealing performance because it makes a large contact stress and small plastic zone size. This new seal system, therefore, may be effective for high internal pressure, under which current gaskets cannot be used.

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REFERENCE

1. Jun Akagawa, Seal Technology, (1972), 365-369, Kindaihenshusha (in Japanese)
2. Nikkan-Kogyo Newspaper, (Dec. 2. 1998), 37 (in Japanese)
3. Hiroshi Otsuji and Masato Nagawa, Japan patent no. 2849345 (in Japanese)
4. Yoshio Matsuzaki, Ph. D dissertation, Fundamental property of metal gasket, Nagoya Institute of Technology, (1993), 27-88 (in Japanese)
5. JIS B 1083 (1990)