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Effect of surface properties on sealing performance of liquid gasket

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It is common practice to use various solid or liquid sealing materials to fill gaps to improve sealing performance, that is sealability, in fastening parts of screws and pipes. Among these sealing materials, liquid sealing materials which is called liquid gaskets or sealants are possible to deform according to the surface geometry of the fastening area and improve the effect of sealing because of their fluidity. To ensure the effect of sealing, the fastening surface which attached each other should be smooth to some extent. Although excessive smoothness increases costs, it is unclear the proper condition of surface geometry for the sealant. It is important to have a guideline for appropriate surface geometry are required. The purpose of this study is to experimentally clarify the relationship between the surface geometry and sealing effect of a liquid sealing material. And ultimately it is to establish a guideline for selecting an appropriate surface geometry. As for the specific implementation method, test specimens with regular geometry were prepared as the surface geometry. The geometries were concentric circles, parabolize and so on with different pitches and depths. This study investigated how the sealant material, pitch, and depth affect the sealing effect of the joint by using two types of liquids, five different pitches, and two different depths in a pattern, while maintaining a constant tightening torque. One of the tightening test materials was made of acrylic, and the sealing process was observed with a high-speed camera. The process of change of the sealant was also observed at regular intervals during the drying of the sealant. For the experiments results, this study discussed the proper conditions of surface properties for sealing.

1. Introduction

A sealant is a material that is applied to a fastening part, such as a flange, to produce a uniform area on the surface of the fastening part to provide a sealing effect on this part. Filling gaps and roughness with these sealants would prevent leakage of fluid during fastening. There are mainly 2 type sealants with solid and liquid.

This study focused on the liquid sealing material (sealant) called liquid gasket. This type has the advantage that do not depend on the shape of the flange. This liquid sealant spreads over the surface of fastening area and could produce a uniform sealing effect on the surface of the fastening area. However, these sealants are possible to deform according to the surface geometry of the fastening area and the sealing effect could change because of their fluidity.

Liquid sealant is a fluid substance that it would dries and homogenizes after application to the joint surface to form an elastic film or thin adhesive layer that improves sealing effect at joints in the ambient temperatures. The sealant is spread evenly over the joint, and the joint is considered to be well sealed when the thin layer of sealant, called "metal touch", is broken off and the joint surface is raised as shown in Fig. 1. When sealant is applied and fastened, air bubbles may occur due to air entering the sealant and fastening surface. These bubbles may form on the bonding surface if air is introduced into the bonding surface during fastening or if gases are generated from the sealant and accumulate on the bonding surface during drying. This may cause problems such as poor sealing and residual harmful gases.

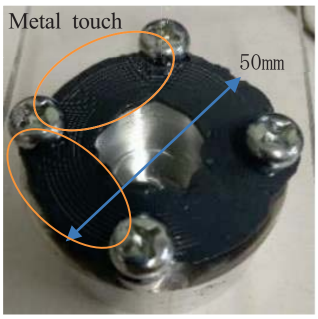


Fig. 1 Example of the flange after metal touch by the seal material.

2. Experimental set-up and methods

2.1 Experimental set-up

2.1.1 Overview of granted texture

For the experiments, some flanges with several types of regular textured surfaces were fabricated by Aluminum. These sealant surfaces are a regular roughness that can be facilitated evaluation and analysis. In the experiments, a flange of about 50 mm in diameter was used to simulate a circular flange, as shown in Fig. 2. And concentric and radial textures were applied to the fastening area. The radial texture was applied to the flange fastening with a milling machine, while the concentric texture was applied with a machining center using a ball end mill with a tip diameter of 1 mm to change the pitch of the concentric circles as shown in Fig. 2 and Fig. 3. Experiments were conducted using a total of 4 textures: 2 radial and concentric shapes with different texture shapes and pitches for easy comparison, and concentric shapes with different pitches, that is, 0.15, 0.20, 0.25, 0.50, 0.87, 1, and 1.25 mm, for comparison in terms of pitch.

Fig. 2 Example of test flange with texture.

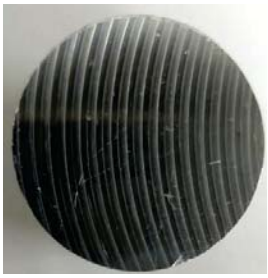


Fig. 3 Example of workpiece machined with milling machine.

2.1.2 Overview of sealant

In this study, we selected a silicone-based sealant whose main ingredient is silicone, which reacts with moisture in the air to cure, and used two types of sealants with different type: Sealant A (the color is red) and Sealant B (the color is dark gray).

2.1.3 System for conducting experiment

The mating side of the flange was a transparent glass or acrylic plate so that the sealant in the fastening area could be seen. The spreading of the sealant was observed with a high-speed camera. A dedicated pressing device using a trapezoidal screw was fabricated. This device is used to press down gradually and evenly with even force as shown in Fig. 4. The mechanism consists of a transparent flange plate attached to a frame fixed to a trapezoidal screw, which is lowered by turning the trapezoidal screw to press vertically against a flange coated with sealant on a stage directly below it while applying pressure.

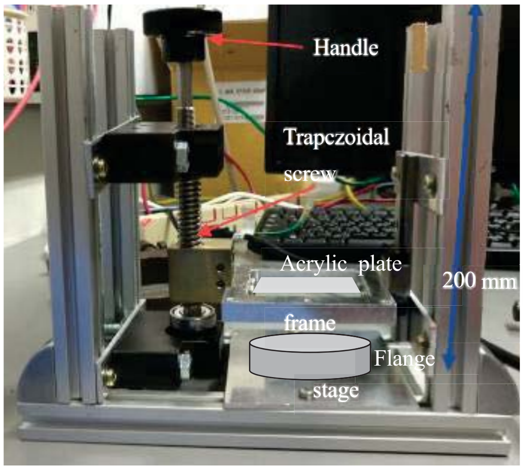


Fig. 4 Experiments device.

2.2 Experimental methods

The comparative evaluation was conducted by observing the appearance of the flange fastening area during pressing, fastening, and drying with a flange with a textured fastening surface. The method was to apply sealant to the surface of the test flange and press a transparent acrylic or glass flange plate on the mating side so that the state of the application could be observed. The appearance of the transparent flange plate when pressed against the flange, the appearance of the screw when tightened, and the drying of the sealant were observed with a high-speed camera as shown in Fig. 5. The changes in the drying process were followed by taking images within 10-minute intervals over a period of five days under a certain experimental condition. To facilitate re-experimentation, a mold release agent was used when applying the sealant. A glass plate was used as a fixed transparent plate for the four types with different texture shapes and pitches, and an acrylic plate was used as a fixed transparent plate for the others.

Fig. 5 Example image of observe device.

Table 1 Results of combinations of concentric flanges.

Texture shape	Experiment number	pitch	Type of sealants	Release agent	Existence of bubble s (drying process)	Existence of bubbles (Tightening process)	Stable metal touch	Empty area
concentric	1	0.15	B	Not used	-	○	○	○
	2	0.2	B	Used	-	○	○	○
	3	0.25	B	Used	-	○	○	○
	4	0.5	A	Not used	-	-	○	-
	5	0.87	B	Not used	-	-	○	-
	6	1	A	Not used	○	-	-	-
	7	1	A	Not used	○	-	○	-
	8	1	B	Not used	-	-	-	-
	9	1.25	A	Not used	○	-	○	-

Table 2 Results of radial shape flanges

Texture shape	Experiment number	Shape roughness	Type of sealants	Release agent	Existence of bubble s (drying process)	Existence of bubbles (Tightening process)	Stable metal touch	Empty area
Radial	10	Rough	B	Used	-	-	○	-
	11	fine	B	Used	○	○	○	-

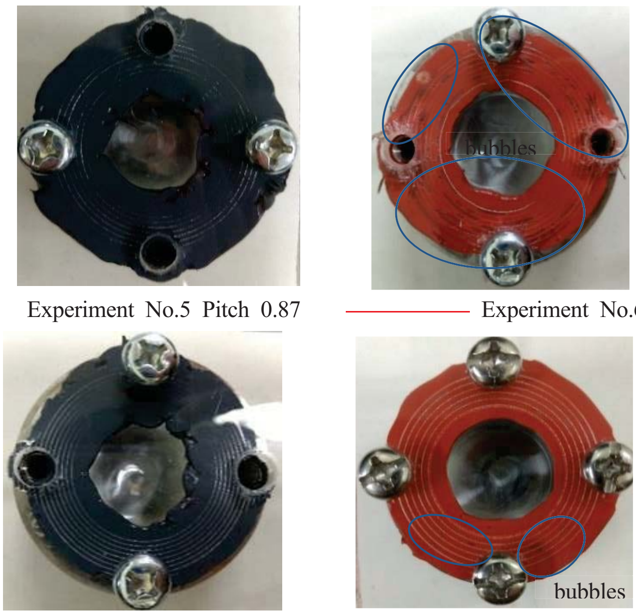
Table 3 Results of concentric shape flanges.

Texture shape	Experiment number	Shape roughness	Type of sealants	Release agent	Existence of bubble s (drying process)	Existence of bubbles (Tightening process)	Stable metal touch	Empty area
concentric	12	Rough	B	Used	○	-	○	-
	13	fine	B	Used	○	○	○	-

3. Experimental results

Experiments were conducted and results obtained with the texture and sealant combinations as shown in Tables 1, 2 and 3 In this result, a pi tch of 1 and 0.5 mm without a mold release agent observed the format ion of bubbles in the bond when thse flange with a pitch of 1 dried. To investigate the cause of the bubbles, we conducted the test again wit h different sealants, one with a pitch of 1 and the other with a pitch of 1.25. Bubbles were observed in both the 1.25 pitch and 1 pitch with th e red sealant A. Bubbles were not observed in the case with a pitch be tween 1 and 0.5, with a theoretical surface height of 0.87, half of the p itch of 1, and with sealant B as shown in Fig. 6.

To make it easier to pee the tightened sealant from the flange, we sprayed the textured surfaces of the joints with a mold release agent. I n the case of the 0.25 and 0.20 pitch, air bubbles were generated durin g tightening, and areas which had no sealant remained (hereinafter ref erred to as "empty areas") were observed near the tightened screws. S uspecting the influence of the mold release agent, we performed the s ame experiment without using the mold release agent and found that bubbles were also generated in the 0.15 pitch. Also, empty area and b ubbles were observed near the tightened screws. Even when mold rele ase agent was used on only half of the textured surface, bubbles were generated, and empty area were observed during tightening when the pitch was small and the surface shape was fine as shown in Fig. 7. To confirm the difference in bubble generation depending on the texture shape and pitch, similar experiments were conducted with concentric circles and radial shapes with large and small pitches. The radial shap e produced no bubbles during tightening and drying as shown in Fig. 8 and Fig. 9, while the concentric shape produced a small amount of b ubbles during drying. Metal touch began to be distributed stably throu ghout the entire surface regardless of the pitch. This suggests that the metal touch is not related to the texture shape, but rather to other facto rs.

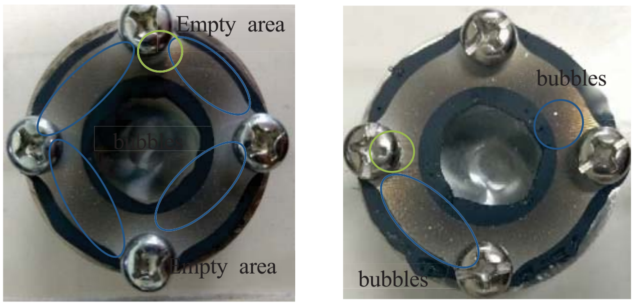


Experiment No.5 Pitch 0.87 — Experiment No.6

Pitch 1.0 Experiment No.8 –Pitch 1 Experiment No.9

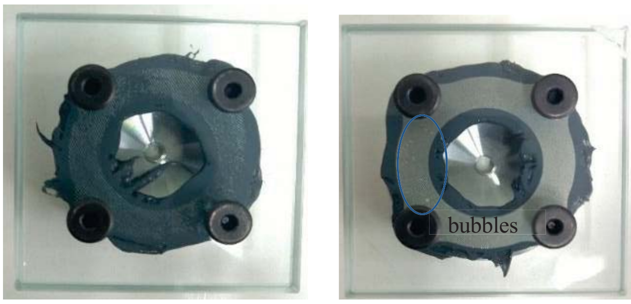
Pitch 1.25

Fig. 6 Concentric texture and sealing material after drying.



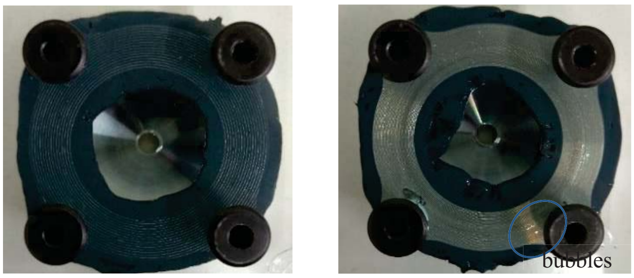
Experiment No.1 Pitch 0.15 Experiment No.2 Pitch 0.20

Fig. 7 Concentric texture and sealing material after drying.



Experiment No.10 Rough texture Experiment No.11 Fine texture

Fig. 8 Radial texture and sealing material after drying.



Experiment No.12 Rough texture_ Experiment No.13 Fine texture

Fig. 9 Concentric texture and sealing material after drying.

4. Conclusion

From these results, it is likely to tell that smaller pitch may cause bubble easier on the tightening process and the larger pitch which is size over 1 may also cause a bubble on the drying process. This could cause poor sealing performance. Since the experiment was not conducted using the other sealant at the same pitch, we would like to conduct experiments using the other sealant and discuss the results in a controlled experiment.

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