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An analysis of changes in flange surface roughness after being used to tighten a corrugated metal gasket

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Abstract. A corrugated metal gasket is not reusable once the plastic deformation has occurred. Meanwhile, flange might be reusable if it has not corroded. This research aimed to find out the surface roughness and contour shape of the flange after being used to tighten the gasket. This study employed a method of measuring the surface roughness before and after the first, second, third, and fourth tightening. The flange used had a surface roughness of Ra 3.5 μ m, Ra 2.5 μ m and Ra 1.5 μ m. The measurement of surface roughness was based on the standard of JISB0601-2001. The findings show that no significant change occurred on the flange surface roughness. However, the corrugated contour shape did occur in the surface roughness after use.

1. Introduction

The use of gasket materials has been terminated following a ban on producing and using asbestos worldwide. A replacement for asbestos materials, therefore, is necessary. Asbestos are used in gasket to prevent leakage in pipes. Gasket is placed between two flanges connected to pipes. To date, the development of gasket materials from metal, i.e. the corrugated metal gasket, has taken place. The function of the corrugated gasket is to decrease the clamping force and produce a spring effect to create a sealing line on the flange.

Research on corrugated metal gasket has been carried out by many scholars. Saeed et al. (2008) initiated the development of the corrugated metal gasket. The gasket had a spring effect and produced a high local stress contact that created a sealing line on the flange [1]. Afterwards, Haruyama et al. (2009) studied the minimum contact width on a gasket using simulation [2]. They found the most optimum contact width in their study. The contact width can be used as the design parameter of the corrugated metal gasket. Through an experiment, it was found that the leakage can be minimized by increasing the contact width. Nurhadiyanto et al. (2012) searched for the most optimum dimension of metal gasket to prevent leakage using a simulation analysis of Finite Element Method (FEM) [3]. Then, the simulation and experiment results were compared. The comparison showed that both results matched each other. With regards to the experiment, the helium leak test indicated that the leakage was not found. Haruyama et al. (2013) studied the force per unit length, contact width, and contact stress for gasket in contact with the flanges with different surface roughness by using FEM [4]. The result of FEM analysis was compared with that of the experiment. The softer the flange surface roughness, the smaller the leakage created using helium leak test will be. The contact between a rough flange surface and a very soft gasket resulted in the rough gasket. Nurhadiyanto et al. (2018) studied the corrugated metal gasket coated with copper [5]. The coating was aimed at softening the gasket surface without changing its stiffness so that the contact stress remains the same. The result of the



simulation was proven with the experiment which showed that the gasket performance increased. The leakage in the copper-coated gasket decreased compared to that in typical gaskets.

These previous studies indicate that the flange surface roughness influences the leakage in the connection. Gasket is easily scratched by the rough flange surface because gasket materials are softer than those of flanges. The gasket surface will become rough as it is in contact with the flange surface. As a consequence, gasket materials fill the roughness of flange surface and repair the leakage. After that, the gasket will deform because of the clamping force. A gasket can only be used for one tightening process. However, the characteristic of flange remains unknown. Is there any change in the flange surface roughness? Is there any change in the flange surface contour? This study aimed at answering these questions.

2. Method

The gasket used in this study was a corrugated metal gasket with two crests and two troughs. Figure 1 shows the corrugated metal gasket coated with copper. The corrugated shape of the gasket was produced using cold press molding. The gasket dimension used was JISB2404 (2006) which was 25A in size and 1.45mm in thickness [6]. Figure 1 shows the gasket used in this study. The gasket material used was SUS304 which was tested using JISZ2241 (2011) [7]. The test result showed the nominal stress of 398.83 MPa, the elastic modulus (E) of 210 GPa and the tangent modulus of 1900.53 MPa.



Figure 1. The Corrugated Metal Gasket.

The flange was based on JISB2220 (2004) with 10K pressure and 25A diameter [8]. Figure 2 shows the flange used in this study. To prevent distortion, the lower and the joint parts of the flange were carefully welded. The detail information on the welding can be found in Haruyama et al. (2013) [9]. The types of flange were differentiated based on the surface roughness parameter (Ra): 1.5 μ m, 2.5 μ m, and 3.5 μ m.

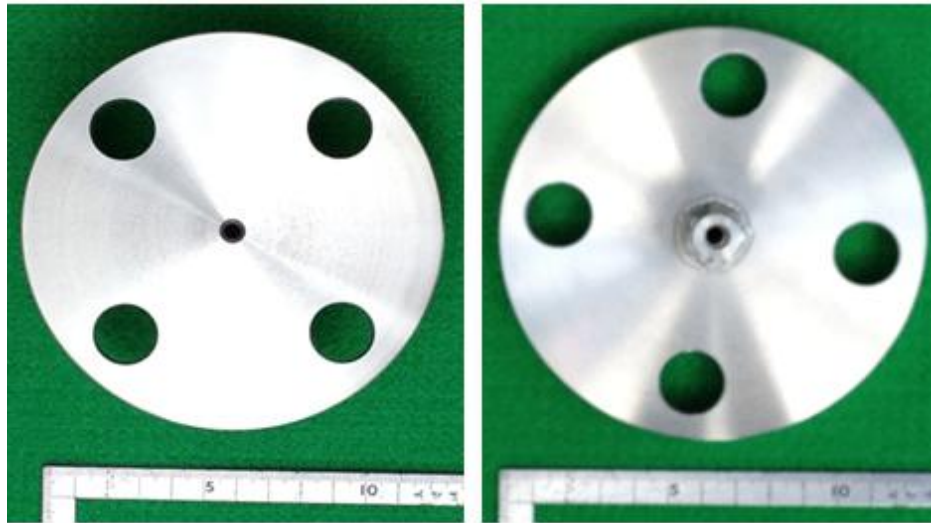


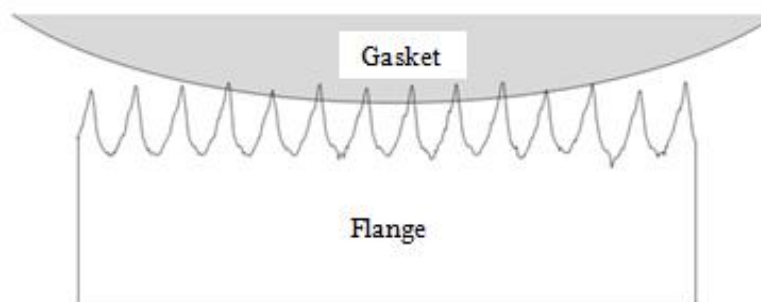
Figure 2. Flange

Previous studies have reported that the leakage was likely to occur as the surface roughness value increased. The simulation result showed that the smaller roughness value increased the contact width [4]. A VH-Z250 series microscope was used to measure the roughness of the gasket surface before and after the tightening process [10]. The microscope helped the researchers measure the grooves of the surface roughness after tightened by the flange. Figure 3 shows the illustration of the grooves of the surface roughness (Haruyama et al., 2014) [11].

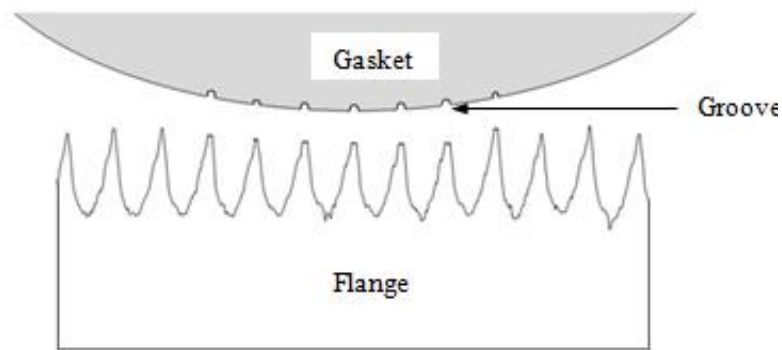
As shown in Figure 3, some grooves on the gasket were found after the tightening between the gasket and the flange. The tightening used bolts which resulted in the high local contact stress on the gaskets crest and trough. Equation (1) shows that the total number of grooves width which mean a real contact width between flange and gasket as explained by Haruyama et al. (2014) [11].

$$CW = \sum_{i=1}^n h_i \quad (1)$$

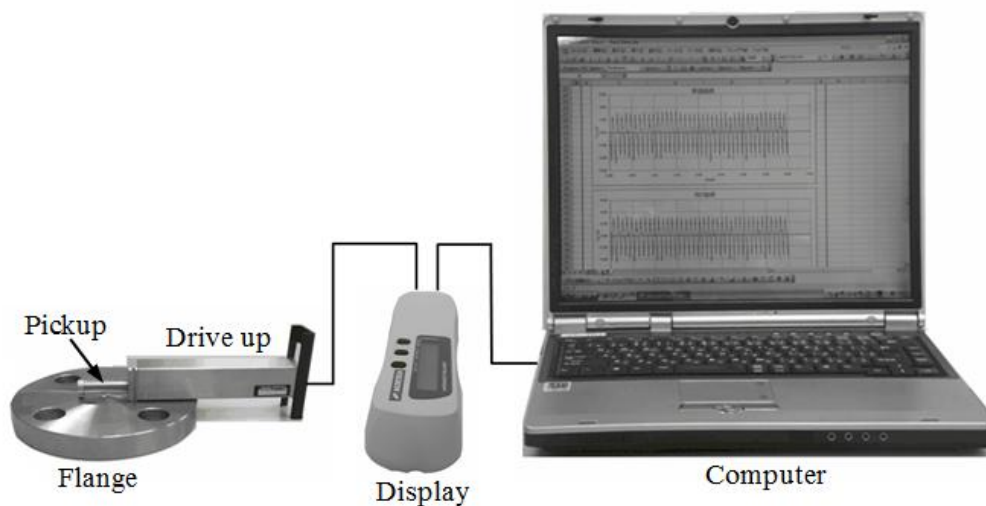
The tools for measuring the surface roughness of the flange are shown in Figure 4. The JISB0601-2001 standard used to measurement of the surface roughness [10]. The data of roughness were measured at four points of contact width which were opposite to one another. The final data were in the form of the average surface roughness of those four points. Further explanations on the measurement of the surface roughness can be seen in Haruyama et al (2013).



(a) Gasket in contact with flange



(b) Groove formed after contact

Figure 3. Gasket in contact with flange and groove formed after contact (taken from [11])**Figure 4.** The measurement of the surface roughness (taken from [4])

There are three kinds of flanges which have the surface roughness of $R_a 3.5\mu\text{m}$, $R_a 2.5\mu\text{m}$, and $R_a 1.5\mu\text{m}$. The measurement of the flange surface roughness was carried out in three situations: before and after the flange use for the first, second, third, and fourth tightening. This study shows the changes the surface roughness and the changes the shape of the surface contour.

3. Results and Discussion

Gasket was deemed not having any surface roughness before use. Once the gasket was used, the grooves appeared because of the flange surface roughness. Figure 5 shows the gaskets surface roughness before and after it was used for tightening. The grooves which appeared showed that gasket materials filled up the flange roughness which eventually repaired the leakage because it was covered by the gasket. It was the purpose of coating the outer surface of the gasket with the softer materials.

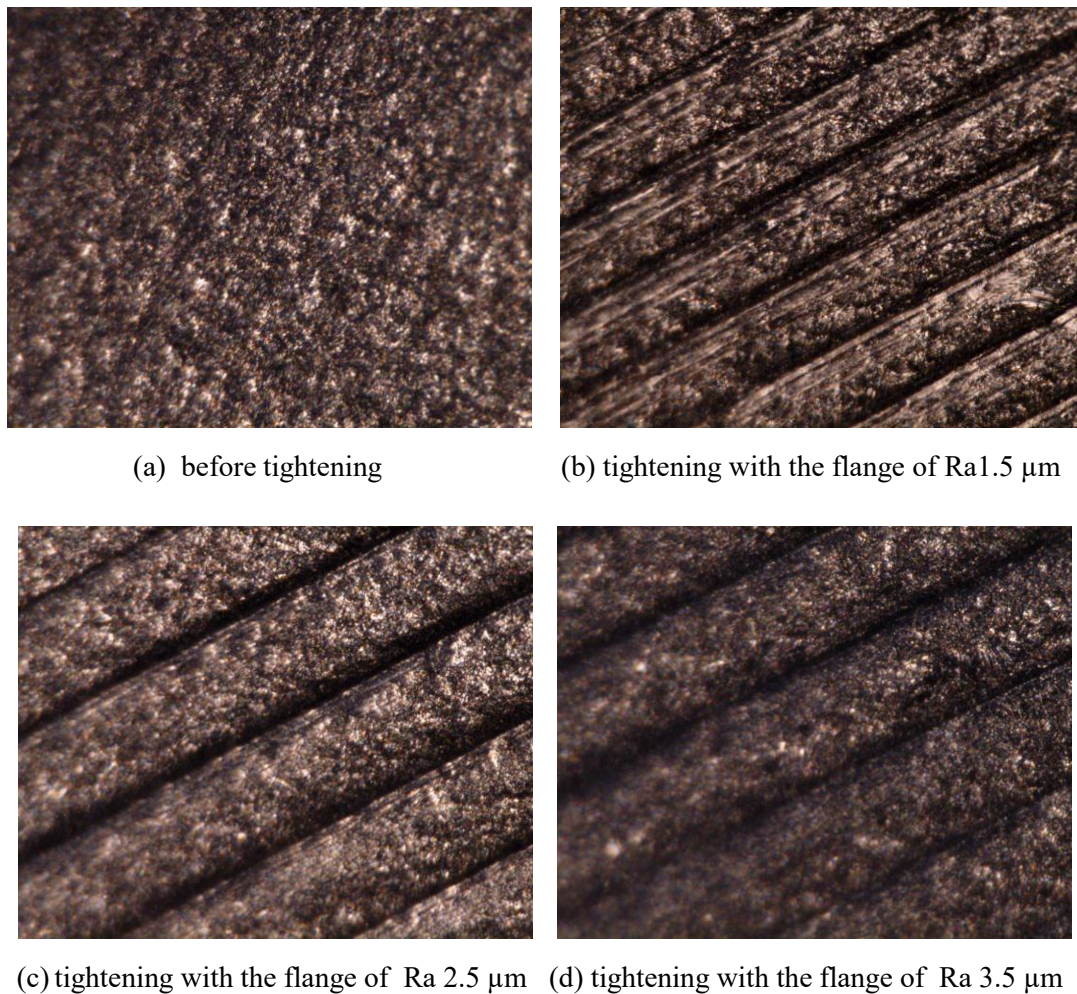
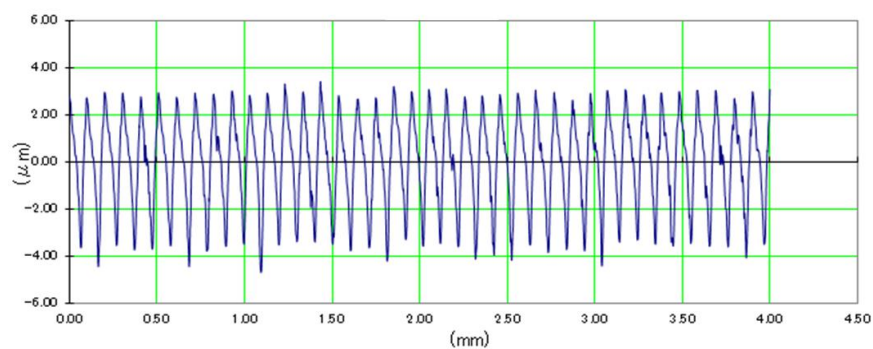
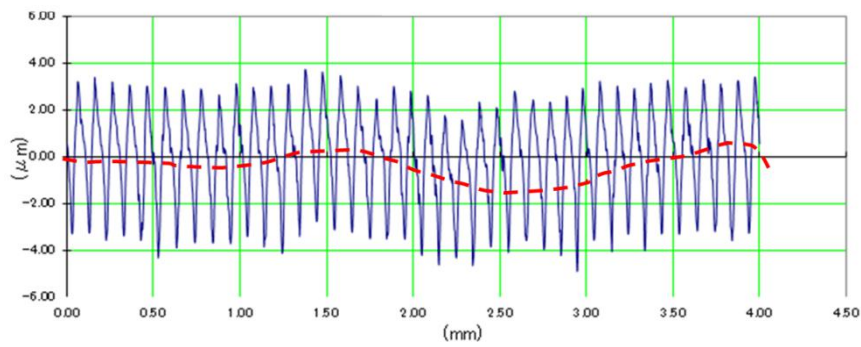


Figure 5. The surface roughness of the gasket

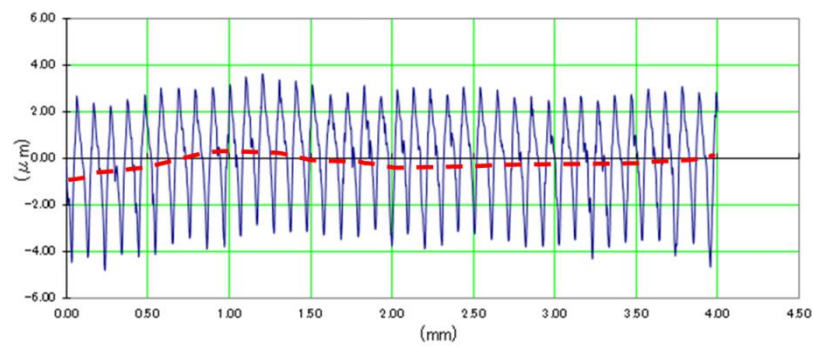
The measurement of the flange surface roughness was done on three kinds of flanges: Ra 3.5 μm , Ra 2.5 μm and Ra 1.5 μm . The measurement result of the surface roughness of the Ra 1.5 μm flange is presented in the form of image in Figure 5. Meanwhile the statistical result is presented in Figure 6, which shows the changes in contour.



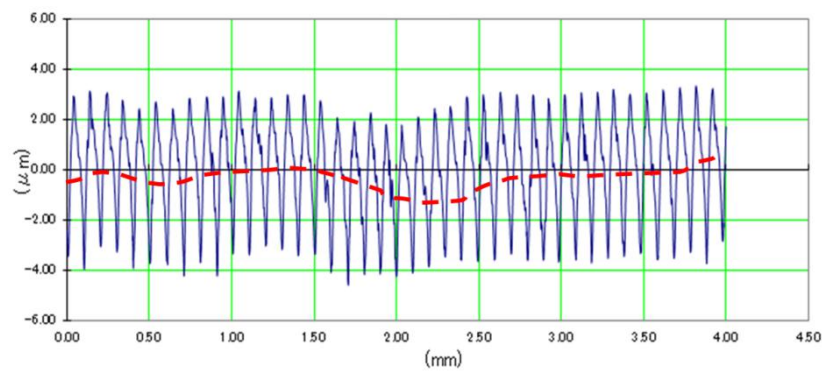
(a) flange surface roughness before used



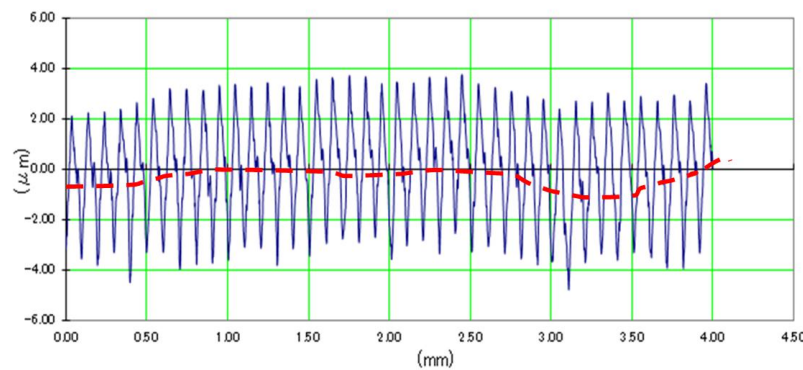
(b) flange surface roughness after the first tightening



(c) flange surface roughness after the second tightening



(d) flange surface roughness after the third tightening



(e) flange surface roughness after the fourth tightening

Figure 6. The measurement of the flange surface roughness

Initially, as shown in Figure 6(a), the midline contour of surface roughness was in the form of a straight line. It means that the surface roughness was symmetrical: the crests and troughs were in balance. The midline contour of the surface roughness changed as the flange was used for tightening as shown by the dashed red line. After the second, third and fourth treatment, the surface roughness experienced contour changes. These changes, however, did not show how big the flange surface roughness value was.

In the same way, surface roughness data for flanges of $Ra\ 2.5\mu m$ and $3.5\mu m$ were obtained. Surface roughness data for $Ra\ 2.5\mu m$ and $3.5\mu m$ showed the same trend as that for $Ra\ 1.5\mu m$. Statistical data of experimental results show that there is a very small change in the flanges surface roughness. The average surface roughness data for flanges can be seen in Table 1. This data is the average data from four points. It is seen that the surface roughness before and after being used for tightening does not change too much. This shows that the flange can be used again after being used for tightening.

Table 1. The flange surface roughness

Surface Roughness	Before used	First tightening	Second tightening	Third tightening	Fourth tightening
Ra 1.5	1.61	1.60	1.60	1.58	1.58
Ra 2.5	2.78	2.78	2.76	2.77	2.76
Ra 3.5	3.91	3.91	3.86	3.75	3.80

4. Conclusions

Based on the above discussion, the following conclusions can be drawn; (1) Gaskets will change the degree of the surface roughness after being used and after tightening process. This surface roughness due to contact with high pressure causes a softer material gasket to fill the surface roughness of the flange; (2) The value of flange surface roughness does not change much before and after use. Flanges can be reused if there is a gasket replacement as long as there is no corrosion; (3) The contour of the flange surface roughness changes. It is no longer in a straight line, but the surface roughness does not change.

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