The Stress Behavior of a Bolt in the

Cylinder-Cover Bolted Joint

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1. Introduction

For the strength design of bolted joints, more strict conditions are required by the recent development of machines and the complexity of modern machine structures.   The design of the cylinder-cover bolted joint is one of such conditions to be analyzed.   The intention of this study is to analyze the stress behavior of the bolt in the cylinder-cover bolted joint, in order to use the analyzed results for developing a strength design system of the bolted joint.   It is considered that the stress behavior of the bolt is varied according to the direction of inserting bolt : The bolt is installed from cylinder-cover side or from flange side.   This is caused by the fact that the cylinder-cover bolted joint has an asymmetric shape concerning with the contact surface between the cylinder-cover and the flange.   It is important for an optimum strength design to clarify the effect of the direction of the inserted bolt on the stress behavior of the bolt.   Computer analysis of the stress for the cylinder-cover bolted joint has already been reported by the authors[1].

This report presents the results of the experiment carried out by changing the direction of the inserting bolt.   The results are discussed by comparing with the data calculated previously under the condition corresponding to the present experiments.

2. Experiment

The cylinder-cover bolted joint used for the experiment is shown schematically in Fig. 1. The dimension for the every part of the cylinder-cover bolted joint is shown in Table 1.   The symbols used in this table are also shown in Fig. 1.   A cylinder-cover was fastened with the six pairs of bolts and nuts.   Two pairs of strain gauges were mounted on the bolt as shown in Fig. 2.   The relation between load and stress in each bolt has been calibrated by using an universal testing machine.   A preload of 29.4 kN was applied to each bolt using the strain

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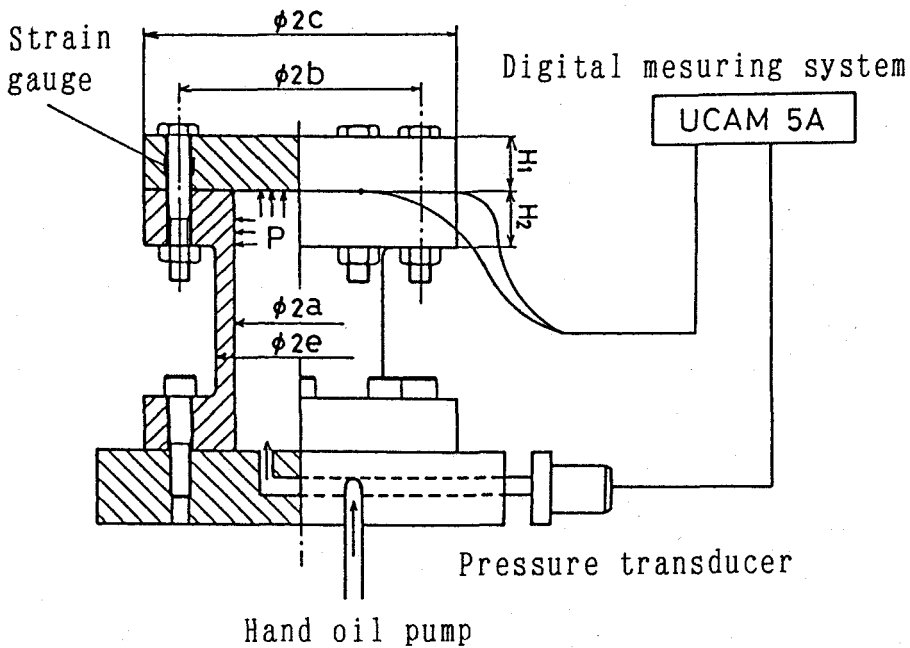* *Kogakuin University, Nishishinjuku, Shinjuku, Tokyo 163-91

Fig.1   Schematic illustration of experimental equipment

Table 1   Geometry of cylinder-cover bolted joint

	2a	2e	2b	2c	H_1	H_2
Type-1	70	90	130	170	15	15
Type-2	70	90	130	170	15	30
Type-3	70	90	130	170	30	15

gauges as an stress indicator. A hand pressure pump was used to apply an internal pressure in the cylinder. A strain gauge type pressure transducer was used to record the internal pressure in the cylinder. The pressure in the cylinder and the strain on the bolts were recorded using a digital static strain meter (UCAM-5A Kyowa Electric Instrument Co.). Figures 3 (a) and (b) show the installed bolts on the cylinder-cover side and on the flange side, respectively. The cases shown in fig. 3 (a) and (b) are respectively called Case A and Case B hereafter, for the convenience of description. The three types of cylinder-cover bolted joint shown in table 1 were measured the relation between the pressure in the cylinder and the stress on the bolt both Case A and B.
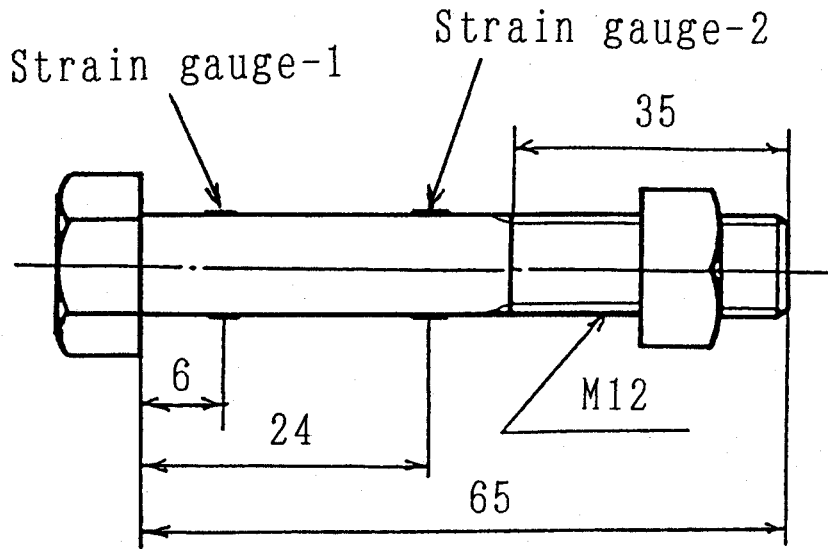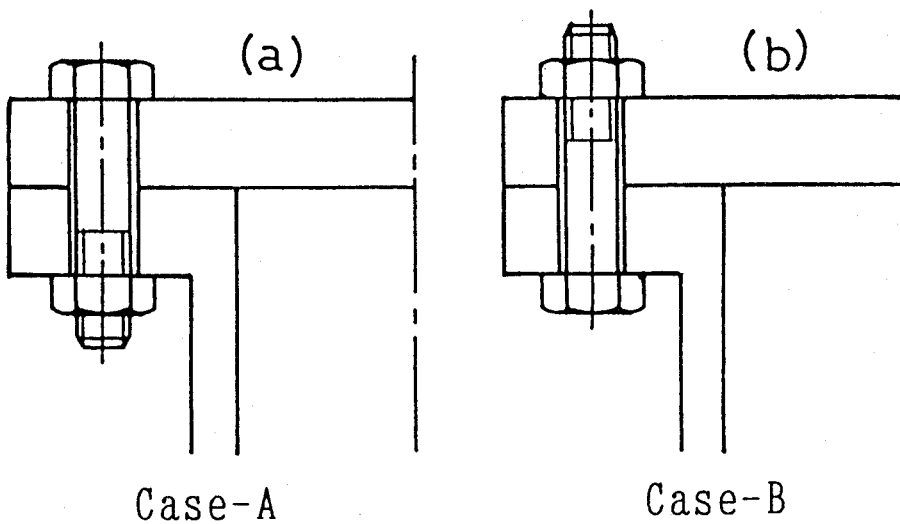
Fig.2   Strain gauges mounted on the bolt

Fig.3   Direction of inserted bolt

3. Results and Discussions

Figure 4 shows the measured relation between the pressure in the cylinder and the axial tension in the bolt. In this figure, the values calculated under the same condition as the experiment are also shown by solid, dotted and broken lines. The experimental results show that the axial tension of Type 1 starts to increase at a lower pressure compared with that of
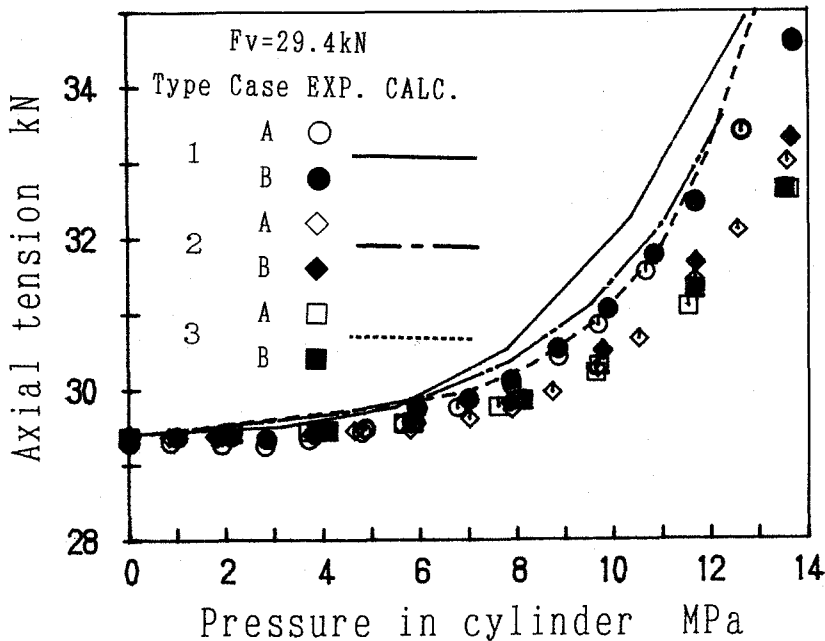
Fig.4   Relation between pressure and axial tennsion

Type 2 and 3.   This is caused by the fact that the grip length for Type 1 is shorter than that for Type 2 and 3.   Moreover, the experimental results show the same increasing rate of the axial tension, although Type 2 is different from Type 3 in cylinder-cover thickness.   The results of Case B obtained for all types in table 1 overlap with the results of Case A obtained by both the calculation and the experiment.   This is explained by the fact that the spring constant for Case A and B are equal to each other since the grip lengths for Case A and B are the same as each other[2].   The results calculated for all the types and cases agree approximately with the experimental results.

Figures 5, 6 and 7 show the relation between the pressure in the cylinder and an additional bending stress in the bolt for Type 1, 2 and 3, and comparison of the results for Case A with those for Case B.

For the experiment with Type 1, the results for both Case A and Case B show a large additional bending stress at the bolt head side (gauge-1).   This is caused by the fact that for both the cases the bending rigidity becomes nearly equal as a result of the same thickness of the cylinder-cover and the flange, as shown in Fig. 5.   For Case B, however, the difference in stress between the bolt head side and the threaded side (gauge-2) is little, since the bending rigidity of the flange is slightly larger than that of the cylinder-cover.   The calculated results for Case A approximately agree with the experimental data.   For Case B, the calculated results show a large increasing rate of the additional bending stress at the bolt head side but
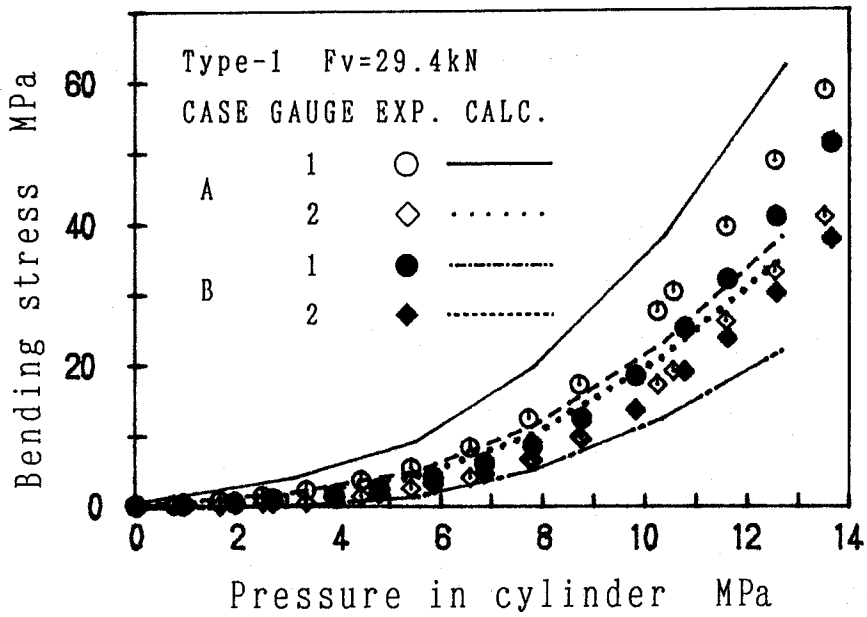
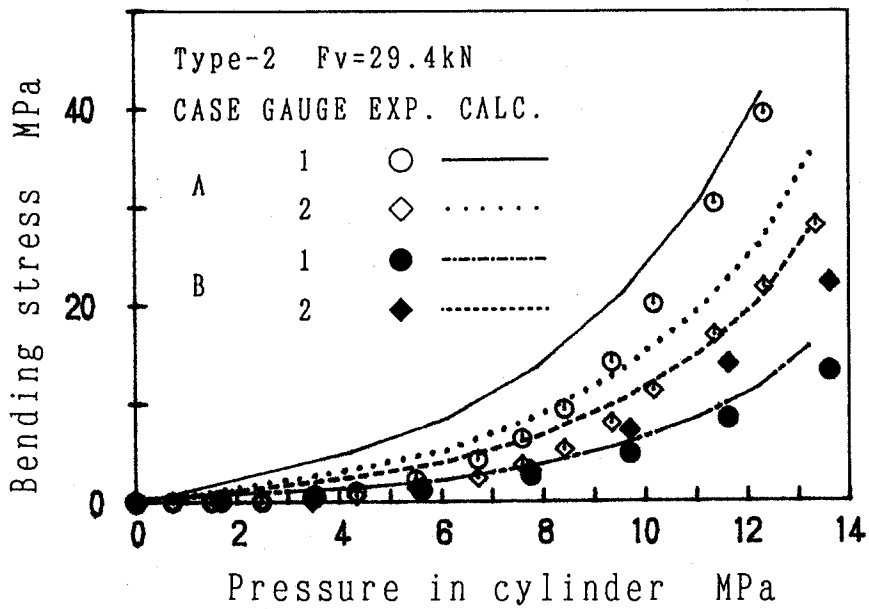Fig.5   Relation between pressure and additional bending stress

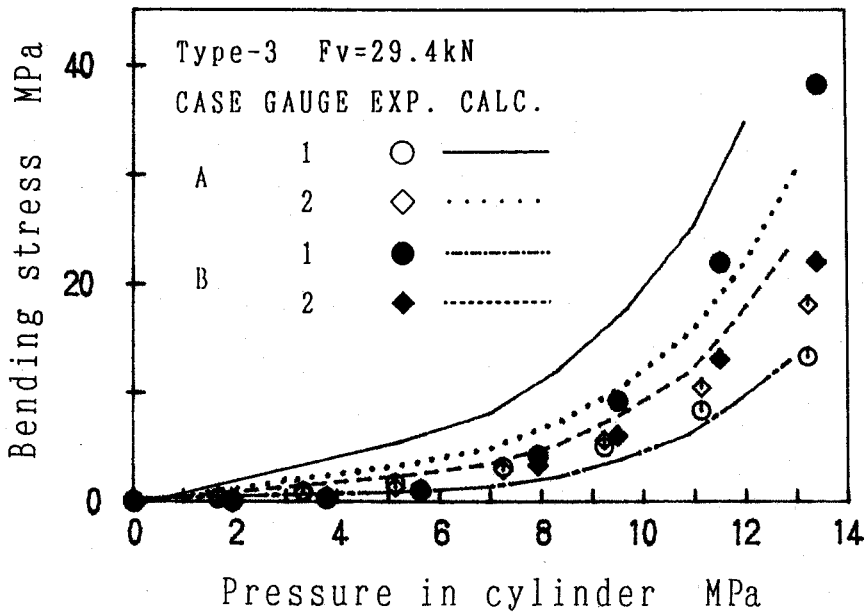Fig.6   Relation between pressure and additional bending stress

Fig.7   Relation between pressure and additional bending stress

the experimental results show a large increasing rate of the additional bending stress at the threaded side, as shown in Fig. 5.   The calculated results, therefor, show opposite tendency to the experimental results in variation of the bending stress.

It is considered that the calculated deflection of the flange is estimated to be lower than its actual value, because the condition of the restricted freedom for the analytical model is not equal to the actual situation.

The experimental results of Type 2 show a large additional bending stress at the bolt head side (gauge-1) for Case A, and at the threaded side (gauge-2) for Case B, as shown in Fig. 6. And then the calculated results for both cases show same tendency for increasing rate of the additional bending stress between the bolt head side and the threaded side to the experimental results.   The results described above result from a considerable large bending rigidity of the flange which is thicker than the cylinder-cover.   The calculated results, therefor, agree approximately with the experimental results because of the lower deflection in the flange.

For the experimental data with Type 3, the large increasing rate of the additional bending stress appears at the bolt head side for Case A and at the threaded side for Case B.   These results show opposite tendency to those with Type 2 in the stress behavior.   This is caused by the fact that the deflection in cylinder-cover which is thicker than the flange is small.   And also the calculated results show opposite tendency to the experimental results in the relation of the bending stress.   This is explained by the same reason described above for Type 1, that

is, the condition of restricted freedom for the analytical model is not equal to the actual situation.

The calculation method described in the ref. 1, however, may be applicable to the general case of the cylinder-cover bolted joint, when the condition of the restricted freedom given for the analytical model is appropriately modified.   This is indicated by the fact that a part of calculated results approximately agree with the results for the present experiment.

4. Conclusion

The results may be summarized as follows:
(1)   If the grip length of each cylinder-cover bolted joint is equal, increasing rate of the axial tension do not change with exchange in the direction of the bolt inserted.
(2)   For the additional bending stress, the stress behavior is regulated by not only the grip length but also the thickness of the cylinder-cover or the flange as well as the direction of the bolt installed.
(3)   The calculated results such as the axial tension and the bending stress in the type where the flange is thicker than the cylinder-cover agree approximately with the experimental result.

References

1. Tanaka, M. and Hongo, K. "The Stress Analysis of Bolted Joint with Model using Spring-beam Elements-A Case of Cylinder-cover Bolted Joint," *J. JSPE*, 55, 7 (1989), p1229
2. Tanaka, M. and Hongo, K. "The Stress Analysis of Bolted Joint with Model using Spring-beam Elements-A Case of T-flange," *J. JSPE*, 54, 2 (1988), p323