# EVALUATION OF THERMAL STRAIN ON CYLINDRICAL ADHESIVE BONDED JOINTS

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**SUMMARY**: In bonding a cylinder and a column, it is difficult to observe the destructive state of a bonded part. The adhesive failure and the material destruction by thermal strain occur, depending on materials and adherents.

Then, by the strain gauge bonded outside of the cylinder, we evaluated the adhesive failure and the material destruction at the heat cycle.

As a result, it was found that the distortion of the circumferential direction was larger than the lengthwise direction and it was found that the thermal strain changed from the kind of the adhesive, the bonding lap length, the bonding layer thickness and so on. Moreover, change of the distortion in curing process was able to be measured.

**KEYWORDS**: thermal strain, cylindrical adhesive bonded joints, distortion, curing process, circumferential direction, lengthwise direction,

## 1. INTRODUCTION

In bonding a cylinder and a column, it is difficult to observe the destructive state of a bonded part. Moreover, depending on the kind of the material and combination, very big heat stress occurs at a heat cycle from the difference of a coefficient of linear expansion, and it is easy to occur adhesion failure and material destruction. In case of a column is steel and a cylinder is a brittle material such as ceramics, large stress is added to the surface of the cylinder in the direction of the circumference by expansion of a steel column and adhesives at high temperature. And then, the cylinder breaks in the direction of an axis. At low temperature, shrinkage of a steel column and adhesives pulls to the inside of the cylinder, and stress is added to the interface of adhesives and the inside of the cylinder. Then, adhesive failure occurs.

The distortion of the cylinder surface with the strain gauge was measured as an evaluation of the cylinder destruction and the adhesive failure occurred by such temperature change. And the influence for the cylinder destruction and the adhesive failure by the kind of adhesives, adhesion layer thickness, and adhesion length, was evaluated. Moreover, the distortion in curing process was measured.

## 2. EXPERIMENT

### 2.1 Distortion measurement of the cylinder surface

Cylinder was the metal sintering material and the column was S35C by steel. Adhesives were applied to inside of steel column and cylinder after washing and degreasing. It inserted rotating cylinder and the overflowing adhesives were wiped off. And then, adhesives were cured. Strain gauges made from special alloy foil with polyimide (Ni-Cr Kyowa Electronic Instruments Co., Ltd.) were bonded to the cylinder surface by epoxy adhesives (EP-34 Kyowa Electronic Instruments Co., Ltd.). Four strain gauges were bonded in the circumferential direction at intervals of 90 degrees and two strain gauges were bonded in the lengthwise direction of both ends of cylinder (Fig.1). Distortion of only a cylinder as a dummy was measured. One strain gauge was bonded on the central part of cylinder for the lengthwise direction, and two for the circumferential direction. (Fig.2)

After cooling an adhesion sample at -20°C from room temperature (25°C), it returned to room temperature (25°C) again, and after heating up to 150°C cooled to 30°C, and the distortion value of all strain gauges were measured.

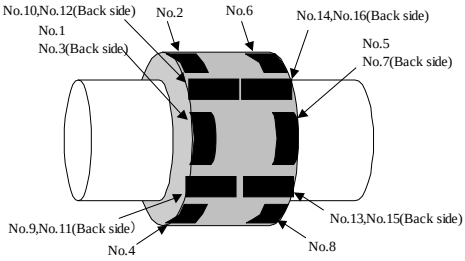



*Fig.1: Adhesion sample*

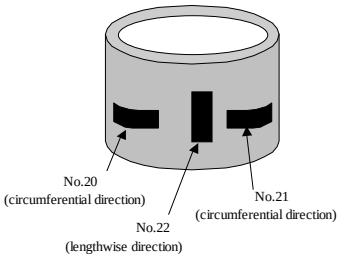



*Fig.2: dummy sample*

### 2.2 Evaluation

**(1) Comparison of the distortion for circumferential direction and lengthwise direction on the cylinder surface**

The distortion value of the adhesion sample and the dummy for the circumferential and lengthwise direction of the cylinder surface was measured. Two parts, epoxy adhesive was used and cured at 60°C for 10 hours. The inside diameter of cylinder was 24.0mm, and a length was 24.0mm, and adhesion layer thickness was from 0.085 to 0.105mm.

**(2) The kind of adhesives**

Three kinds of adhesives were used; two parts, 60°C for 10 hours curing epoxy adhesive, two parts, room temperature curing acrylic adhesive, and one part, 135°C for 15 minutes curing epoxy adhesive. The inside diameter of cylinder was 36.3mm, and a length was 22.5mm, and adhesion layer thickness was from 0.06 to 0.105mm.

**(3) Adhesion layer thickness**

Adhesion layer thickness was varied from 0.05 to 0.30mm. Two parts, room temperature curing acrylic adhesive was used. The inside diameter of cylinder was 36.3mm, and a length was 45mm.

**(4) Adhesion length**

Two kinds of cylinders were used, the inside diameter was 36.3mm, and a length was 22.5mm and 45mm. Two parts, room temperature curing acrylic adhesive was used. Adhesion layer thickness was 0.105mm.

**(5) Curing process**

Two kinds of adhesives were used; two parts, 60°C for 10 hours curing epoxy adhesive, and two parts, room temperature curing acrylic adhesive. The inside diameter of cylinder was 36.3mm, and a length was 45mm, and adhesion layer thickness was 0.105mm.

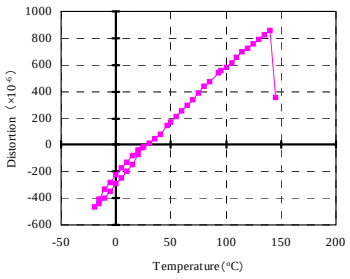
## 3. RESULT

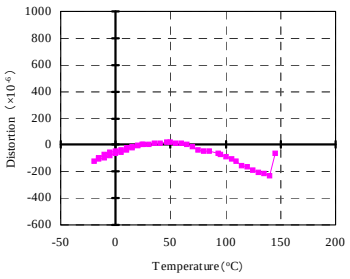
**(1) Comparison of the distortion for circumferential direction and lengthwise direction on the cylinder surface**

The distortion measurement result in the circumferential direction of the cylinder surface was shown in Fig.3. The distortion of the cylinder surface has decreased while lowering the temperature from the room temperature. The column and the adhesive shrank, the cylinder was also reduced, and the compression stress acted on the circumferential direction on the cylinder surface. When the temperature is raised to the room temperature again, the distortion value has increased with almost the same inclination while the temperature was decreased. The distortion value has increased linearly while cooling. The column and the adhesive expanded, the cylinder was also expanded, and the strain stress acted on the circumferential direction on the cylinder surface. When rising temperature up to 145°C, the distortion value was decreased suddenly in all measuring points. This is because the crack was caused by the increase of the strain stress in the circumferential direction on the cylinder surface. When the sample was taken out and observed there were some cracks.

The distortion measurement result in the lengthwise direction on the cylinder surface was shown in Fig.4. It has been understood that a distortion value in the lengthwise direction is smaller than that in the circumferential direction.

The distortion measurement result of a dummy sample was shown in Fig.5. The distortion values of the circumferential and lengthwise direction were small. Therefore, it is thought that the distortion in the direction of the circumference of the bonding body shown in



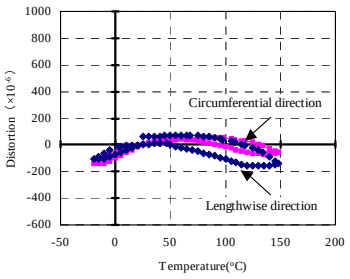




Fig. 3 shows the influence of change by the column and the adhesive.

**(2) The kind of adhesives**



*Fig.3: The circumferential distortion on the cylinder surface*

*Fig.4: The lengthwise distortion on the cylinder surface*

*Fig.5: The distortion of a dummy*

In case of two parts, 60°C for 10 hours curing epoxy adhesive, the distortion value suddenly changed at -5°C and 75°C. When color check was done after examination, big crack was found as shown in Fig. 6. On the other hand, in case of two parts, room temperature curing acrylic adhesive and one part 135°C for 15 minutes curing epoxy adhesive, the distortion value didn't change suddenly. No crack was found as for color check either.

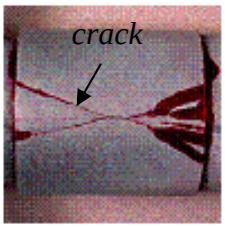



*Fig.6: The cylinder surface after color checking*

**(3) Adhesion layer thickness**

Two parts, room temperature curing acrylic adhesive was used. Table 1 showed the temperature the distortion value greatly changed. When the thickness of the adhesion layer became large, the temperature of the cylinder destruction shifted to the high temperature. It is considered that adhesion layer ease the stress by expansion of a column.

**(4) Adhesion length**

In case of the length of the cylinder was 45mm, the distortion value changed suddenly at about 130°C, and the crack was found. On the other hand, when the length of cylinder was 22.5mm, no crack was found.

*Table.1: Adhesion layer thickness and the temperature of the distortion change*

| Adhesion layer thickness | Direction change High temperature side | Low temperature side |
|---|---|---|
| mm | °C | °C |
| 0.051 | 120-125 | -20 |
| 0.1 | 125-135 | -20 |
| 0.2 | 150 | <-20 |
| 0.299 | 140-150 | <-20 |

**(5) Curing process**

In case of two parts, 60°C for 10 hours curing epoxy adhesive, the distortion value changed at curing process heating at 60°C and cooling to room temperature, shown in Fig.7. It showed that the distortion has collected at room temperature in case of two parts, 60°C for 10 hours curing epoxy adhesive. In case of two parts, room temperature curing acrylic adhesive, the distortion value changed at curing process, shown in Fig.8.

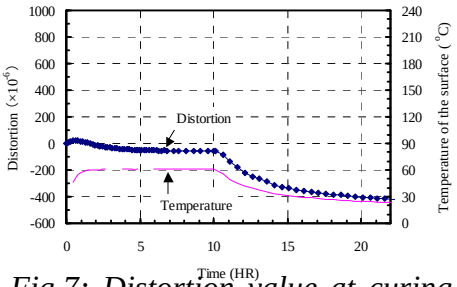



*Fig.7: Distortion value at curing process in case of two parts,* 60°C for 10 hours *curing epoxy adhesive*

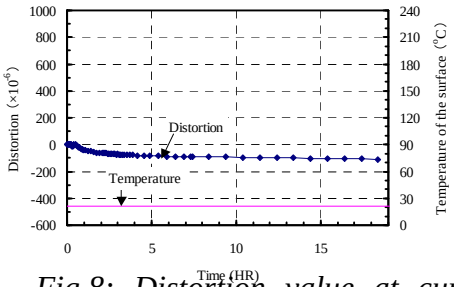



*Fig.8: Distortion value at curing process in case of two parts, room temperature curing acrylic adhesive*

## 4. CONCLUSION

The distortion of the cylinder surface by the temperature change was measured clearly with the strain gauge. The distortion in the circumferential direction was larger than the distortion in the lengthwise direction. It was able to be detected that the destruction of the cylinder

occurred at high temperature. The distortion in the circumferential direction decreased suddenly when the destruction of the cylinder occurred. It was found that the kind of the adhesives, adhesion layer thickness and adhesion length influence easing the stress by the expansion of the column. Moreover, it was found that the distortion in curing process was able to be measured.