

# Development of Brake Caliper Production Process with High Strength Al-Li Material

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## ABSTRACT

A production process was developed that uses high-strength Al-Li materials to reduce the brake caliper weight. Anisotropy of material strength due to metal flow was eliminated with 3-axis multi forging, and an 8% increase in fatigue strength was achieved by T6 heat treatment with 3-stage aging. This is expected to increase the service life to 4 times that of current calipers.

## 1. Introduction

Reducing a vehicle's unsprung weight contributes to enhancing its vehicle dynamics, so brake caliper weight reduction is demanded. A caliper development project was started with the aim of reducing the weight by 150 g per caliper (600 g per vehicle). As the current caliper materials, the 2099 materials of aluminum-lithium (Al-Li) alloy is used, which are high stiffness, low density aluminum materials. However, these materials have anisotropy of material strength, which posed design restrictions. Therefore, a forging process was established with the aims of eliminating anisotropy of material strength, and a heat treatment was developed with the aim of increasing strength.

## 2. Developed Technology

### 2.1. Selection of Materials

Figure 1 shows the material properties of the Al-Li alloy, and Fig. 2 shows the anisotropy of material strength from the fatigue strength in the longitudinal (L) and transverse (T) directions of the materials. The fatigue strength data of 2618 materials for the piston is also shown for comparison reference.

Under Formula One regulations, caliper materials are prescribed as aluminum materials with a Young's modulus of 80 GPa or less. As the current material, a 2099-T83 extrusion bar of Al-Li alloy is used that displays low density, high strength, and high Young's modulus. However, this material has anisotropy of material strength, and the low T direction strength restricted the design.

### 2.2. Forging Process for Eliminating Anisotropy of Material Strength

Anisotropy of material strength could not be eliminated by 1-axis forging of the 2099 extrusion bar. Therefore, 3-axis multi forging was applied, which is an effective method for eliminating anisotropy of material

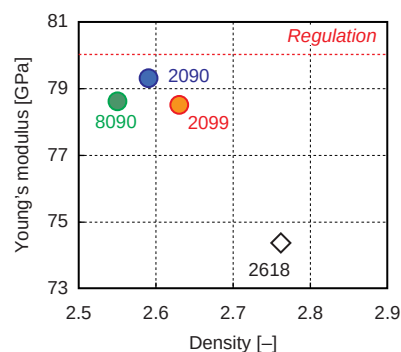


Fig. 1 Modulus and density



Fig. 2 Fatigue property

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strength. Before die forging, 50% upset forging from the three X, Y and Z axes was performed to eliminate anisotropy of material strength by a hydraulic press. Figure 3 shows the set forging process.

### 2.3. Heat Treatment Conditions for Increasing Strength

The 2099 materials are a deposit strengthening type alloy, with  $\sigma'$  deposit phases ( $\text{Al}_3\text{Li}$ ) and  $T_1$  phase ( $\text{Al}_2\text{CuLi}$ ) deposit phases. Cold compression to introduce a dislocation that serves as the deposit phase core is an effective means of increasing strength, but this is difficult to apply to calipers, which have a complex shape. Heat treatment with multi stage aging is also effective in generating a core for the deposit phase<sup>(1)</sup>, so T6 heat treatment with 3-stage aging was developed with solution treatment for 2 hours at 549°C, followed by aging (treatment) for 48 hours at room temperature, 24 hours at 120°C, and then 100 hours at 165°C as the heat treatment conditions for the 2099 forged materials.

The status of each deposit phase was analyzed using a transmission electron microscope (TEM) and differential scanning calorimetry (DSC), and the following mechanisms of deposit strengthening were confirmed: 1) formation of a GP zone by room temperature aging, 2)  $\sigma'$  phase deposition by 120°C aging, and 3)  $T_1$  phase deposition with the GP zone as the core by 165°C aging.

### 2.4. Evaluation of Material Properties of 2099 Forged Materials

Prototype 2099 forged materials for calipers were manufactured using the 3-axis multi forging process and

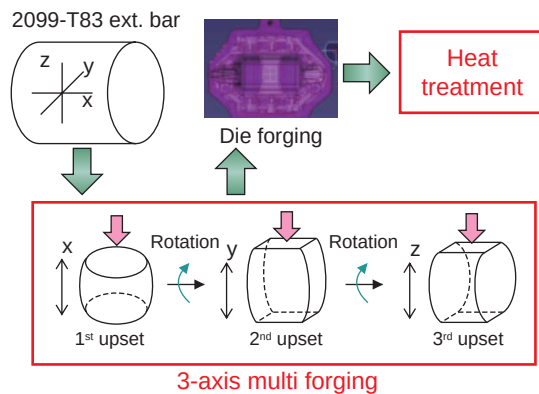


Fig. 3 Caliper forging process

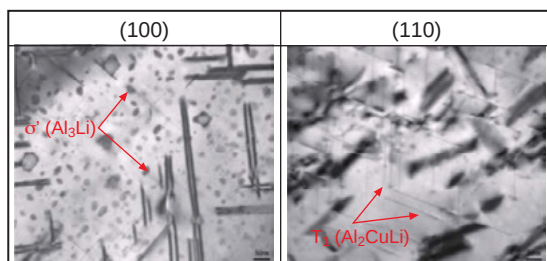


Fig. 4 TEM photograph of 2099 after 3 stage T6 ( x 150000 )

T6 heat treatment with 3-stage aging. Test pieces were sampled in the L and T directions of the 2099 forged materials as shown in Fig. 5, and tensile-tensile fatigue tests were performed.

Figure 6 shows the results. The current 8090 and 2099 extrusion bars exhibit anisotropy of material strength, with the fatigue strength differing according to the location from where the test piece samples were taken. However, the developed 2099 forged materials introduced in this paper had the same fatigue strength regardless of sample location, so anisotropy of material strength was eliminated. In addition, an 8% increase in fatigue strength was confirmed relative to the T direction of the 2099 extrusion bars, which had been a design restriction. As a result, the strength in the weakest area of the part was increased, giving prospects for a four-fold increase in durability.

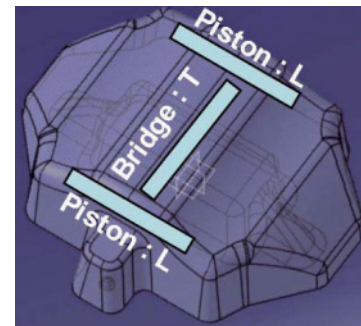


Fig. 5 Sampling regions

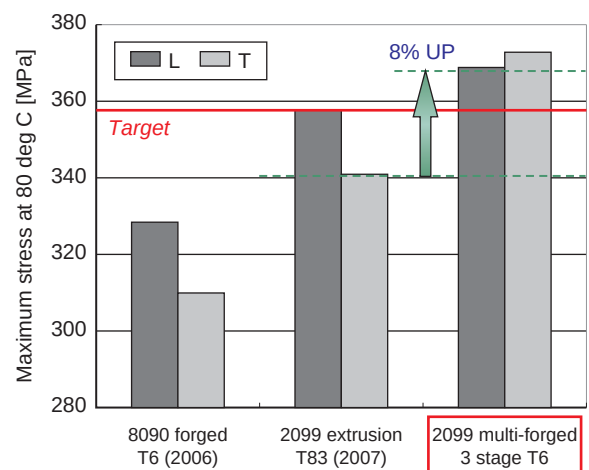


Fig. 6 Fatigue property of caliper body materials

## 3. Conclusion

This development established production process technology that eliminates anisotropy of material strength by 3-axis multi forging, and increases fatigue strength by 8% compared to the current materials by T6 heat treatment with 3-stage aging. Converted to service life, this increased durability by 4 times.

## Reference

- (1) Romios, M., Tiraschi, R., Parrish, C., Babel, H. W., Oqren, J. R., Es-Said, O. S.: Design of Multistep Aging Treatment of 2099 (C458) Al-Li Alloy, Journal of Materials Engineering and Performance, p. 641(2005)

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