

Development of Plastic Organ-type Accelerator Pedal Assembly

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ABSTRACT

An organ-type pedal attached to the floor by a pivot has been developed to increase the comfort of accelerator pedals. The trace of the new pedal is in the same phase as the motion of the sole of the human foot.

A plastic hinge structure has been adopted for the pivot. Tests on a plastic hinge structure were conducted. Results showed that polyester elastomer possessed superior fatigue resistance, therefore, this was selected as the hinge material. The newly developed thin hinge has enabled the new pedal to equal conventional pedal structures in strength and durability. The hinge section was immersed in oil, grease and other chemical agents to test durability, and results showed no change in physical properties.

The connection of the pedal to the floor was also altered. The flexibility of the material has enabled snap-fit assembly, and the connection is strong enough to resist an extraction load of over 900 N.

1. Introduction

The overhung accelerator pedal shown in Fig. 1 is the conventional design among accelerator pedals for passenger vehicles.

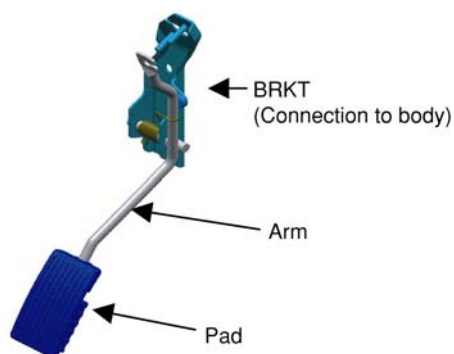


Fig. 1 Conventional accelerator pedal assembly

The overhung accelerator pedal consists of a bracket attached to the vehicle body above the pedal, a metal arm, and a pad. This structure is widely used because it is simple, requires few parts, and is cost efficient.

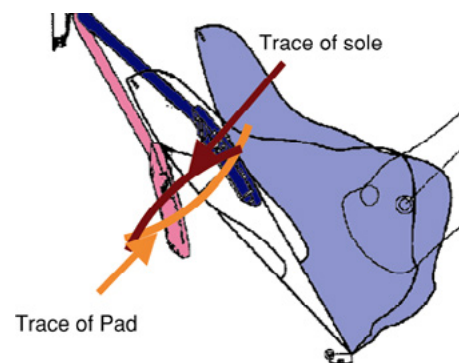


Fig. 2 Trace of conventional accelerator panel

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The issue with this pedal is that the arc, which the pad follows (Fig. 2, Trace of Pad), is different from the arc of the sole of the driver's foot (Fig. 2, Trace of Sole). This makes it more difficult to provide a good feel to the pedal during operation.

Matching the trace of the pad to the trace of the sole is essential for improving the feel of the overhung accelerator pedal. For example, a comfortable feel is possible with an organ-type pedal because the pedal is fixed on the floor while the bottom of the pad is pivoted so as to move. If the pad on an overhung accelerator pedal were simply extended and attached to the floor, this would interfere with the operation of the pedal. Therefore, we investigated an organ-type pedal structure, using as many of the existing components of the conventional overhung-type as possible for component reliability. As shown in Fig. 3, the new structure was proposed in which the pad of the overhung-type was extended downward and connected to the floor with a pivot, and a hinge was provided with the pivot to make it movable. This paper describes a newly developed plastic accelerator pedal that has a mounting structure integral with the floor.

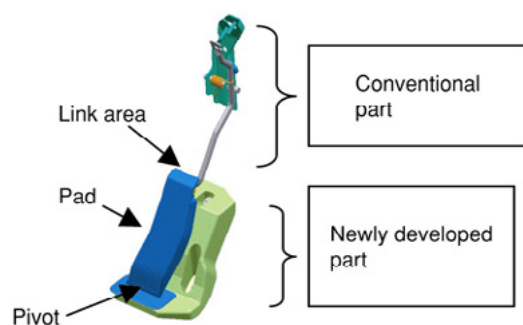


Fig. 3 Accelerator pedal assembly

2. Technical Elements of Development

Figure 4 shows details of each component of the pedal displayed in Fig. 3. The plastic pad was fixed to the floor and the hinge area was designed so that the entire pad is movable,

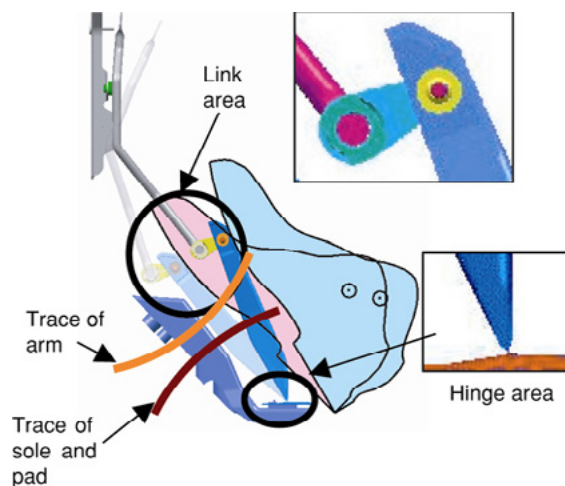


Fig. 4 View of hinge pivot and link area

enabling the traces of the sole and pad to be identical. There is still divergence between the trace of the arm of the conventional structure and the trace of the pad; this is accommodated by the link mechanism. In addition, the mounting structure of the hinge area must be firmly attached to the floor in order to support the movement of the entire pad.

The following technical elements were developed in order to realize this structure:

- (1) Specifications and durability of the plastic hinge
- (2) Vehicle mounting structure
 - Establishment of the mounting structure on the floor
 - Establishment of the link structure to absorb discrepancy with arm motion

3. Specifications and Durability of the Plastic Hinge

The plastic hinge structure for the new accelerator pad requires both tolerance of fatigue due to the repeated motion and adequate strength against operating forces.

Optimal materials and component shapes to satisfy these requirements were investigated. For material selection, it was decided to use test pieces as shown in Fig. 5. The test piece was flat and featured a hinge section in the center, as shown in Detail C. The basic thickness of the piece was 1.0 mm, but the hinge section was 0.5 mm thick.

Two types of polypropylene (PP-B and PP-C) were selected for the plastic material because these are reported to offer superior qualities for hinge function⁽¹⁾. Two types of polyester elastomer were also selected because these

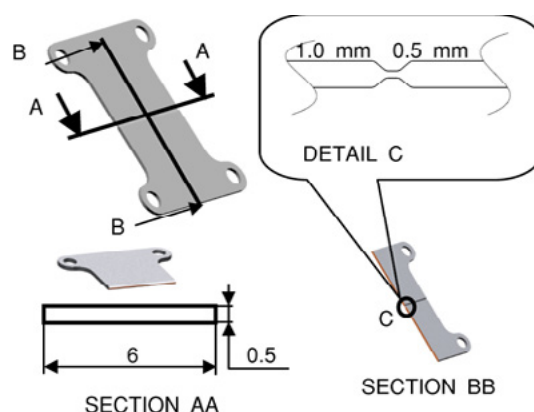


Fig. 5 Test piece

Table 1 Material property

Item	Unit	Material				
		PP			Polyester	
		A	B	C	D	E
Tensile strength	MPa	19	20	21.5	7.8	14.2
Elongation	%	150	350	>500	610	390
Flexural modulus	MPa	1370	1320	1080	70.6	210
Izod Impact	J/m	88	98	196	NB	NB
MI	—	15	9	3	8	8

possessed elongations above the target value of 300%. Finally for comparison, PP-A, a material with an elongation of 150% was also selected for a total of 5 materials tested. Table 1 presents the representative properties for each of these.

3.1. Fatigue Test

The durability test was carried out as follows. A test apparatus was built that subjected only the hinge section of each test piece to motion in order to evaluate the durability under conditions matching actual use. Figure 6 shows the principle of operation of the apparatus. The upper edge of the hinge test piece was fixed, and the lower edge was connected to an arm that moved so as to flex the hinge. The structure allowed adjustments of various rotation angles. Figure 7 shows the entire test equipment. The gate-shaped upper fixture and the mobile arm of the lower section are plainly visible. Specimens shaped as shown in Fig. 5 were tested in cold and hot environments, at temperatures from -30°C to $+80^{\circ}\text{C}$. The superiority of the material was assessed by the percentage of retained tensile strength after testing. The retained tensile strength was measured after 3 million cycles at each rotation angle and at different cycle numbers up to 3 million cycles under a constant rotation angle of 45° .

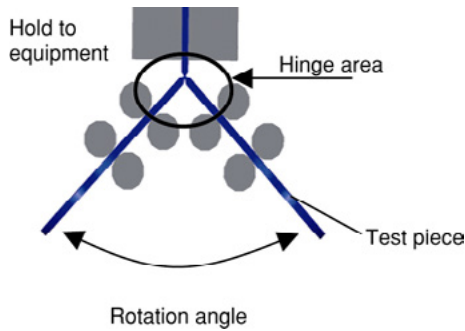


Fig. 6 Schematic of durability test



Fig. 7 Test equipment

Figures 8 and 9 show the retention rate of tensile strength after a 3 million cycles durability. Figure 10 shows the retention rate of tensile strength after the various cycle numbers at the rotation angle of 45° .

The results in Figs. 8 and 9 indicate a dependence of the

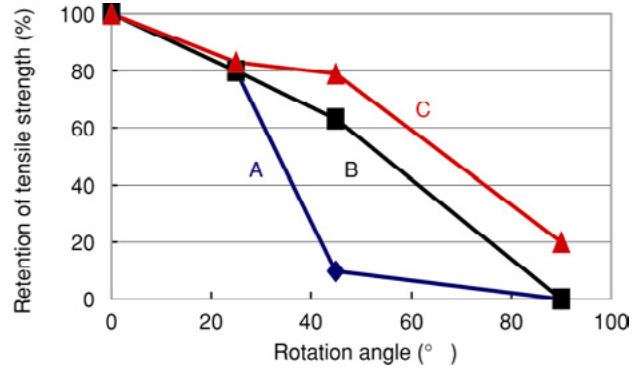


Fig. 8 Retention of tensile strength after durability test (PP)

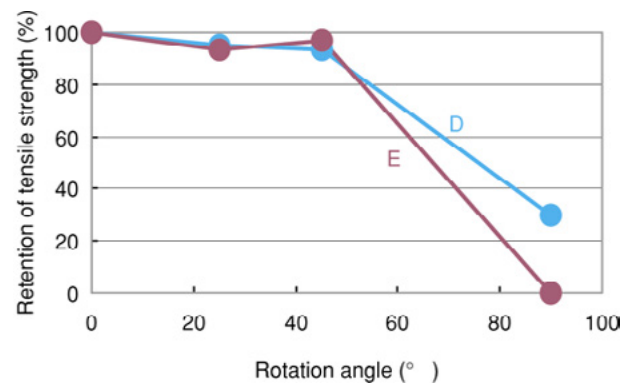


Fig. 9 Retention of tensile strength after durability test (Polyester)

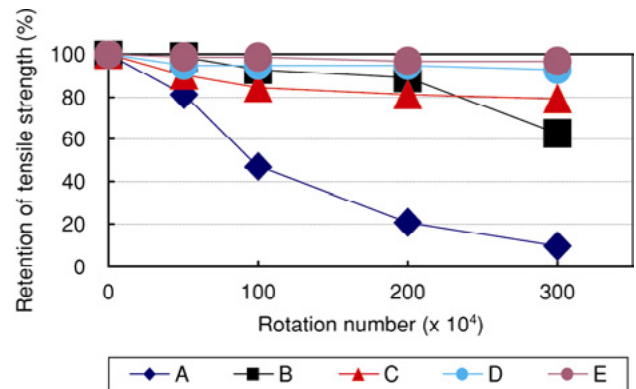


Fig. 10 Retention of tensile strength after durability test (for each rotation number)

decrease in retained tensile strength on rotation angle in both PP and polyester elastomers. The greater the rotation angle, the greater the degradation in strength. Comparison of the A, B and C types of PP in Fig. 8 showed that hinge performance in durability was affected by material elongation; the type with elongation below 300% showed a sharp degradation in the 45° rotation region. The polyester elastomers had superior

fatigue properties; both materials D and E showed almost no degradation in tensile strength after the durability test at angles of 45° or below. The results in Fig. 10 for each rotation number show that the PP demonstrated gradual reductions in retained tensile strength after 500,000 cycles, while polyester elastomers demonstrated almost no such reductions through 3 million cycles.

According to the layout, the operating rotation angle in the actual pedal hinge will be less than 45°; therefore, it was decided to use the polyester elastomers, which demonstrated no strength degradation after a durability test at this operation rotation angle.

3.2. Strength Tests

The superiority of polyester elastomers was verified by the fatigue tests. Test pieces shaped as shown in Fig. 5 were subjected to three further strength tests in order to identify the best hinge shapes and materials. Two types of hinge shape were tested: Type 1, a piece with a straight part at a thin hinge section in order to reduce the stress concentration; Type 2, a piece with a thin hinge section.

(1) Tensile strength test

Input load is applied to the entire hinge

(2) Shear load test

Input load is applied at the tip of the hinge

(3) Torsion torque test

Input torsion load is applied about the axis at the center of the hinge.

The test methods and results are shown in Figs. 11, 12 and 13. The results of the strength tests for shape showed that the initial strength of Type 1 was higher for all three tests within the same material.

Within the same shape, there was a dependence of strength on material tensile strength; polyester elastomer E proved superior.

From the above results, polyester elastomer E was chosen as the hinge material, and Type 1 was chosen as the hinge shape. For good hinge function, the thin section was designed at 0.5 mm thickness, and the length of the straight part was set at 1.0 mm in order to prevent stress from concentrating on the hinge section.

3.3. Chemical Resistance

The following tests for chemical resistance were carried out on polyester elastomer E, which had shown superior fatigue durability and strength performance.

The elastomer was soaked for 72 hours in six chemicals including oil, grease and gasoline to which it could commonly be exposed to in everyday use, and the physical property change was re-checked.

The fraction of retained strength in tensile loading was used as the parameter for physical property change. The results are shown in Fig. 14.

Retained strength was over 90% for all chemicals. It was verified that polyester elastomer E had nearly no degradation in physical properties.

4. Structure for Mounting on Body

4.1. Establishment of Mounting Structure on Floor

The pad in the organ pedal must be connected to the floor mount, in contrast to the requirements of the conventional structure.

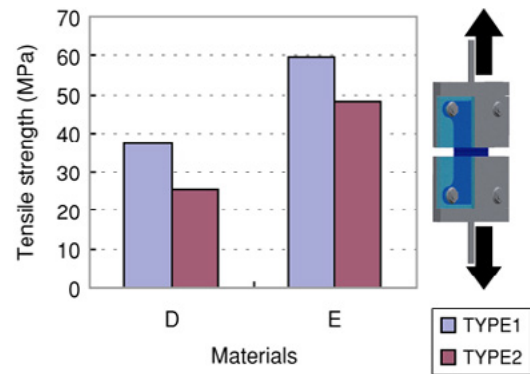


Fig. 11 Results of tensile strength test

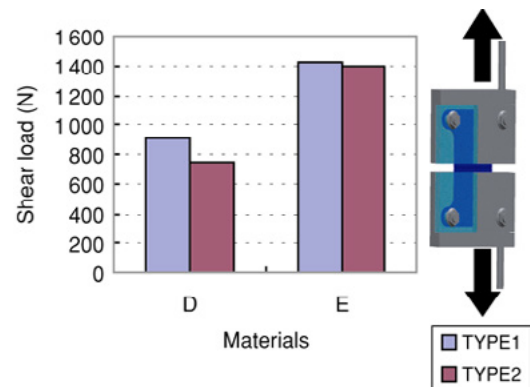


Fig. 12 Results of shear load test

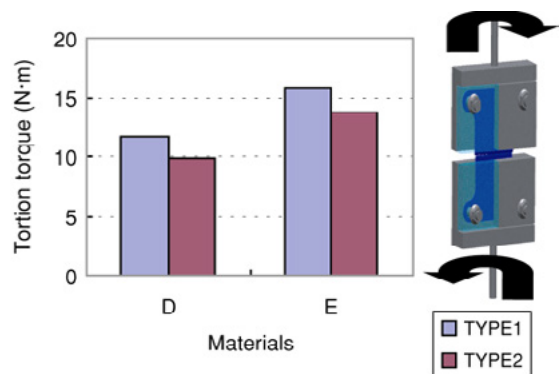


Fig. 13 Results of torsion torque test

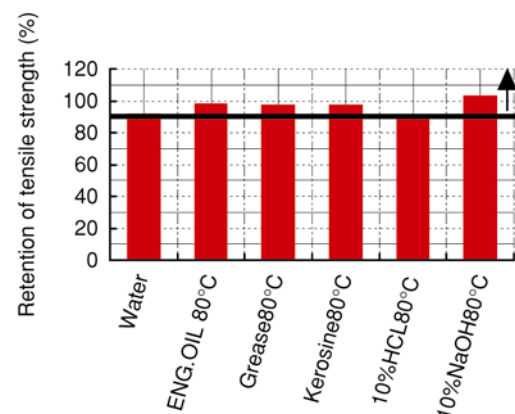


Fig. 14 Results of chemical resistance test

Figure 15 shows each part of the connecting section of push-in snap-fit construction that was considered to be convenient to use between the pad and the stopper on the floor mount.

The snap-fit construction satisfies several requirements: ease of assembly (assembly with a single hand motion), strength (difficulty of accidental disassembly) and ease of maintenance (easy removal). An integral back-plate was designed on the stopper to fix the pawls on the pad. The back-plate is shown in Fig. 16(a).

During attachment, the back-plate is pushed down, while the pawls of the pad are inserted into the stopper, as shown in Fig. 16(b). The back-plate flexes to allow the pawls to enter the inside of the stopper, as shown in Fig. 16(c).

Once the pawls have been pushed in all the way and opened, the back-plate springs back upward, as shown in Fig. 16(d), being clipped by the pawls. If an extraction load is exerted on the pad, the pawls would have to flex inward so as to exit, but the back-plate inside the pawls prevents them from flexing inward. This provided toughness to the mechanism against disassembly; it resisted a load of over 900 N. On the other hand, it is easy to disassemble the mechanism for maintenance by inserting a tool or other object to depress the back-plate. This eases maintenance tasks. The extraction load on the pads and stopper was measured after 100 repetitions of assembly and disassembly; it was at a level similar to that during initial assembly.

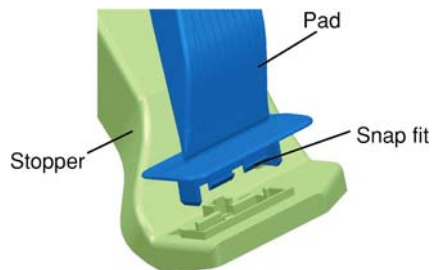


Fig. 15 Snap fit connection

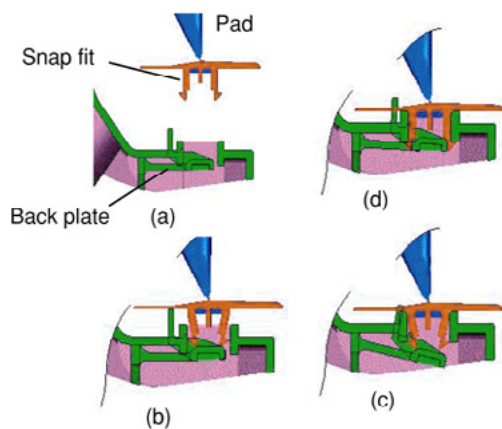


Fig. 16 Snap fit mechanism

4.2. Establishment of Link Structure to Absorb Discrepancy with Arm Motion

Figure 17 shows a detailed drawing of the link installed between the upper structural components from the previous structure and the organ-type pad. The link-arm is allowed to pivot about the shaft and is held in place with the push-nut. Figure 18 shows operating positions of the link-arm and the pad when the pad moves by being pushed with the foot. The cross angle of the link arm and pad changes due to the differences in traces of the arm and the pad, but the link-arm operates smoothly, as it is supported via two points, the pivot of the pad and the pivot of the arm.

Section A-A from Fig. 17 is shown in Fig. 19. Spherical shape bearings were selected in order to absorb variations in parallelism, and a sliding link structure was used to absorb scatter in components and assembly.

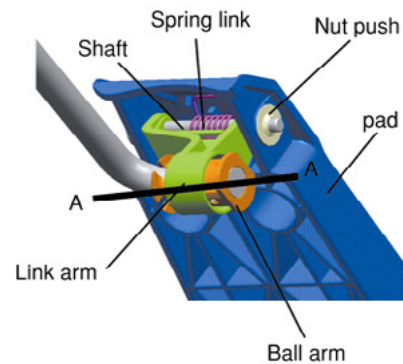


Fig. 17 Link area

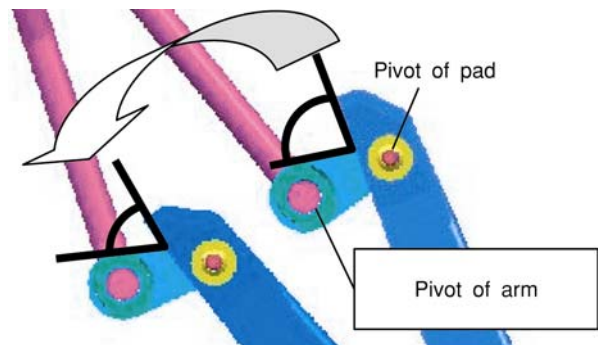


Fig. 18 Mechanism of link section

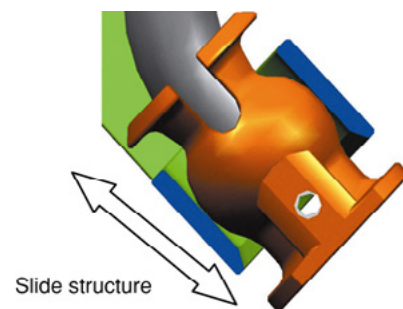


Fig. 19 Linkage of link arm and ball arm

5. Results for Operating Feel in Actual Vehicle

The operating feel in an actual vehicle of the plastic organ-type accelerator pedal developed in this project was investigated.

Figure 20 shows the relation between pedal stroke and operating load. In the overhung pedal, there is a non-linear increase in operating load with pedal stroke; as a result, there tends to be a heavy feeling against the sole of the foot in the latter part of the stroke. In the organ-type pad, however, the increase of operating load is linear with pedal stroke.

There was also an improved, firm feel to the organ-type pedal. This is attributed to the greater width at the bottom of the tapered organ-type pedal, as shown in Fig.21. The fact that the pad is connected to the floor at the bottom also may contribute to this because this structure restrains the movement of the lower part of the pad.

Tests in actual vehicles confirmed that the organ-type accelerator pedal provides an improved operating feel.

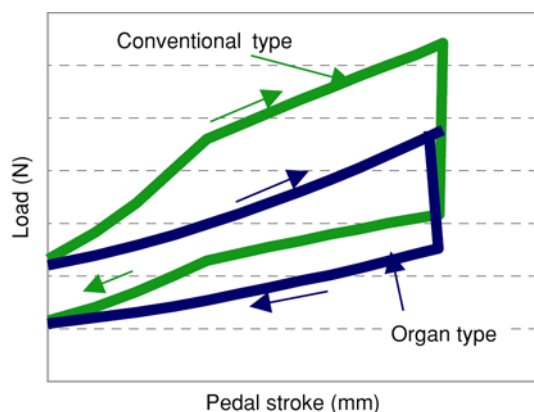


Fig. 20 Comparison of feel of load



Fig. 21 Pad shape

6. Conclusion

We developed the organ-type accelerator pedal which offers durability and reliability at a level equal to that in accelerator pedals of conventional construction and provides a good operating feel because its arc matches the arc of the sole of the foot. The technical elements of this development are mentioned as follows.

(1) Methods for evaluating the materials and structures of the plastic hinge mechanism were conceived and showed that both polypropylene and polyester elastomers demonstrated degradations in durability at rotation angles of over 45°. These were particularly marked in PP.

- (2) Materials with elongations of over 300% are suited for hinge mechanisms operating at angles of 45° or lower. Polyester elastomers have superior fatigue properties.
- (3) A durable and high-strength organ-type pedal was developed by combining the hinge structure of the polyester elastomer. The structure is provided with a straight part at the hinge to avoid stress concentrations.
- (4) A strength of over 900 N was obtained in the structure of the joint where the pedal is attached to the floor by designing a snap-fit, which exploited the potential of soft material, resulting in a structure offering easy assembly and easy handling during maintenance.
- (5) The design and acceptance of the link structure, which allowed use of components of the conventional accelerator pedal, enabled mounting of the organ-type pedal on a car body.

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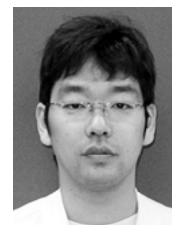
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