ECU for Small Motorcycles Produced by Transfer Molding

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1. Introduction

In the motorcycle industry, the environmental consciousness of major consuming countries has increased and the fuel injection system (F/I) has been promoted for many years. However, compared to the previous fuel supply system, there is a greater number of components, which leads to an increase in cost, and this has hindered popularization of F/I. Therefore, we have promoted the introduction of F/I by continuously promoting cost reduction of conventional systems. However, in order to promote the distribution of F/I to major consuming countries at an early stage and thus reduce the environmental burden, it was necessary to adopt innovative technology and greatly reduce the cost of F/I related products.

In this report, we introduce an electronic control unit (ECU) produced by transfer molding (T/M) which maintains the conventional performance and functions. Components have been integrated and downsized, and with process innovation, the newly developed ECU is less expensive than conventional products. We will also introduce our efforts on the production line.

2. Approach to Innovation

We analyzed existing products and searched for components to be improved. We decided to

explore ways to integrate the connector, the case, and the mold (3 elemental components) that account for a large portion of the cost. We promoted the development project with the following two concepts.

(1) integration of three elemental components
(2) innovations in the production process

3. Integration of Three Elemental Components

As shown in Fig. 1, in order to integrate the three elements, the case and connector functions were incorporated into the mold and the circuit board.

In regard to the method of achieving this, as shown in Fig. 2, a card edge type circuit board was adopted and sealed with a thermosetting epoxy resin (hereinafter referred to as sealing resin). By structuring the unit to suit the female connector, we

Rubber seal Electronic components

Card edge type circuit board

T/M resin (Thermosetting Epoxy)

Fig. 1 Cut model and components of T/M ECU
were able to attach the unit side connector directly to the circuit board, thus integrating the connector, circuit board and case, and reducing the size and cost of the components.

In this test, the destruction mode was checked, the reliability of various components was evaluated, and components suitable for molding were selected.

4.2. Development of Thermosetting Resin and Circuit Board

From the viewpoint of obtaining good molding capability and adhesion, the development activities shown below were performed.

(1) Optimization of molding conditions

(2) Control of viscosity and curing characteristics during resin flow

(3) Improvement of adhesion properties

Ultrasonic testing equipment (SAT) was used to reveal peeling, as shown in Fig. 4.

Areas that look white are in a peeled-off state. In the next chapter, we will explain the problems that occurred in activity (3) Improvement of adhesion.

4.1. Electronic Component Selection

Due to the transfer molding, the pressure applied to the electronic components is relatively low, but it is necessary to select electronic components suitable for molding. Therefore, molding tests were conducted for each component, and the component conditions were confirmed.

An example of a failed component is shown in Fig. 3.

In this example, it was observed that the resin material penetrated into the electronic component.

4. Approach to Resin Mold Structure

If electronic components to be mounted are not hermetically sealed, damage may be caused by vibration or heat load.

In addition, protection from external factors (water, dust, etc.) is not possible, and the reliability is greatly reduced.

In the connector and caseless structure, it is necessary to form the structure (shape) of the conventional connector and case. In addition, it is necessary to select and design electronic components adapted to the molding environment and structure.

4.1. Electronic Component Selection

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5. Control of Adhesion

From analysis of the interface, we contemplated the mechanisms of adhesion and peeling in order to control adhesion.

5.1. Confirmation of Adhesion Mechanism

The state of the functional group at the bonding interface was observed using an atomic force microscope (AFM) and infrared spectroscopy (NanoIR).

The measurement point indicated by a white line in the AFM image (Fig. 5) is an IR continuous spectrum (Fig. 6).

Transition was observed at C = O peak height around 1724 cm\(^{-1}\) (Fig. 7).

Based on this fact, the adhesion mechanism is presumed to be a chemical interaction, and not a physical interaction at the interface.

5.2. Identification of Adhesion Inhibitory Factors

In chemical interaction, the surface chemical state of the adherend contributes to adhesion stability.

In order to identify surface substances that inhibit adhesion, the surface of the substrate on which both adhesion success and failure events were observed with by X-ray photoelectron spectroscopy (XPS).

The result is show in Fig. 8. It was identified that adhesion was inhibited by a very thin deposit of organosilicon.
5.3. Success or Failure of Adhesion

From the confirmation results of adhesion inhibition, as indicated in Fig. 9 it is considered that the molding was completed in the order of (1) to (4), and peeling occurred.

We designed and managed the production process in order to control the chemical state of the surface, thus achieving a stable adhesion quality to improve reliability.

In addition, the production process was designed so that the circuit board maintains adhesiveness by making the article to be bonded uniform near the edge of the circuit board, an area where peeling is likely to occur after the thermal cycle test (Patent pending).

(1) Reduction of unnecessary processes due to integration of components
(2) Process automation
(3) Traceability

In this digest, (2) process automation and (3) traceability are described in detail.

6.1. Process Automation

In order to accomplish a reduction in cost, we investigated automation of the processes for labor saving. All molding processes are carried out by automatic machines, with only the materials being loaded by the operator.

We abolished the identification label which we used for the conventional product, and the unit details are automatically recorded after molding with laser marking instead.

At the attachment of the connector seal, front and rear identification, movement of the workpiece, assembly of the connector seal, and alignment of the workpiece are performed completely automatically.

We also adopted an automatic machine for the electrical characteristics inspection process.

The new line is shown in Fig. 10.

By the above means, a fully automated system is accomplished with the subsequent reduction in labor.

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Fig. 9  Schematic diagram of process

6. Process Innovation

In order to integrate the three elemental components, it was necessary to design an optimum production line according to the changes in structure and manufacturing. In addition, another requirement was to create an efficient line capable of producing high quality products.

Therefore, in order to achieve reform of the manufacturing process (process innovation), the following approaches were taken.
6.2. Traceability

Traceability is strongly required from the viewpoint of quality control.

In the new line, as shown in Fig. 11, the situation at each production process is recorded in the company server as manufacturing information for each product, and passage through all processes is managed. We have striven to stabilize the process, improve production quality, and strengthen the quality control system through daily automatic information management.

![Traceability system structure](Image)

**Fig. 11** Traceability system structure

7. Summary

T/M was adopted and realized to integrate reconstitute the combination of the three main elemental components of the ECU. We established the necessary technology, evaluation methods, and manufacturing control methods for molding and sealing of the product. By automation of the production line, we have reached a high level of efficiency, reduced labor, ensured operator safety, and engineered the line for product quality stability. The comparison with a conventional product is shown in Table 1.

Through these efforts, we have secured the quality of small motorcycle ECUs and introduced an inexpensive and compact product.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Comparison between conventional and T/M ECU</th>
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</thead>
<tbody>
<tr>
<td>size (mm)</td>
<td>56 × 78 × 30</td>
</tr>
<tr>
<td>Occupied volume</td>
<td>131040mm³</td>
</tr>
<tr>
<td>weight</td>
<td>Approximately 110g</td>
</tr>
<tr>
<td>working process</td>
<td>-</td>
</tr>
<tr>
<td>Production facility area</td>
<td>-</td>
</tr>
<tr>
<td>Production personnel</td>
<td>-</td>
</tr>
<tr>
<td>Production capacity</td>
<td>-</td>
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**Author**

S. TAKIOKA

I deeply appreciate the people inside and outside of the company who have greatly cooperated in promoting this development. (TAKIOKA)