

Development of High-pressure Diecast Magnesium Intake Manifold

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ABSTRACT

A magnesium high-pressure diecast (Mg HPDC) intake manifold has been used in the newly developed V6 Integrated Motor Assist (IMA) engine on the ACCORD Hybrid for the North American market.

The body of the intake manifold features the same split structure used in the aluminum high-pressure diecast (Al HPDC) intake manifold fitted in the Honda ELYSION. The two parts of the body are sealed with a formed in-place gasket (FIPG). This FIPG is also used in Honda's high-pressure diecast magnesium transmission case. A modified version of a metal gasket has been used for the seal of fuel injector base.

The new magnesium high-pressure diecast (Mg HPDC) intake manifold is 44% lighter than a conventional aluminum low-pressure diecast (Al LPDC) intake manifold and 33% lighter than an Al HPDC intake manifold.

1. Introduction

One means of addressing global environmental issues, is to attain enhanced fuel economy. The application of magnesium alloys has expanded in recent years as an effective means of reducing vehicle weight.

To date, Honda has used the AZ91D magnesium alloy for engine head covers and the AM50A Mg alloy for steering wheels. Honda has also used a heat resistant magnesium alloy for the engine oil pan and manual transmission case.

As part of their continued efforts to reduce engine weight, the authors have developed a Mg HPDC intake manifold, a major component of the V6 engine.

2. Development Goals

The development goal for this project was to achieve a lightweight intake manifold capable of handling a 300 ps level high power engine. This would be done by changing the Al LPDC intake manifolds adopted for Honda's V6 engines to that of a Mg HPDC manifold using existing technology and mass production facilities.

The authors set the following targets for development, in order to achieve the weight reduction with Mg HPDC.

- (1) The targeted intake manifold must have seal performance, as well as strength and durability, equivalent to that of the mass-produced Al LPDC intake manifold.

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- (2) The target manifold must attain noise and vibration characteristics equivalent to those of the Al LPDC unit.
- (3) Casting of large, thin-walled parts using the Mg HPDC method must achieve product quality equivalent to that of Al HPDC parts.

3. Structure and Configuration

3.1. Basic Structure

As shown in Fig. 1, the intake manifold unit is composed of two parts: the intake manifold upper and the intake manifold lower. The joining surfaces are sealed using a FIPG, and are then bolted together.

An upper cover and an injector base, as well as a throttle body, are later bolted to the intake manifold unit.

In addition, a stainless steel EGR pipe is bolted inside the intake manifold, and a steel joint is inserted at the external hose connection.

3.2. Separation Structure

The Mg HPDC intake manifold unit is comprised of a plane separation area and a three-dimensional separation area, as shown in Fig. 2.

3.2.1. Port breaking structure

With the Mg HPDC intake manifold, a three-dimensional separation structure was adopted in order to create a port shape capable of handling a 3.5L 300 ps high power engine. When a plane separation structure is used, as shown in Fig. 3(1), the port is shaped like an L and the airflow is not smooth. This led to the decision to use a three-dimensional separation structure. When the port shape is shaped with a smooth curve as shown in Fig. 3(2) the air flows more easily.

3.2.2. Throttle body mounting flange separation structure

By giving the throttle body mounting flange a plane separation structure, the throttle body mounting flange, as shown in Fig. 4(1), is comprised of an intake manifold upper and intake manifold lower.

This structure forces the throttle body sealing surface to be machined together after the intake manifold upper and intake manifold lower are assembled. The result is a complex procedure, consisting of part machining, followed by assembly, followed by machining the surfaces together. To avoid such a procedure, the throttle body mounting flange side is given a three-dimensional separation structure in the outer flange area, as shown in Fig. 4(2). This allows the throttle body mounting flange surface can be machined as a single intake manifold lower part.

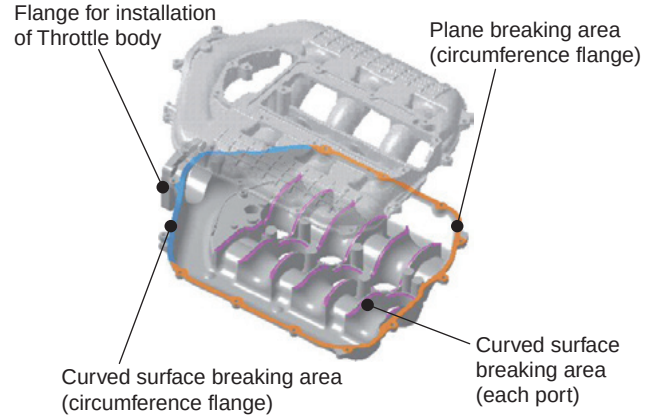


Fig. 2 Breaking structure

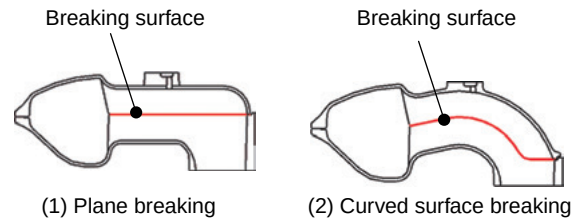


Fig. 3 Section shape of port

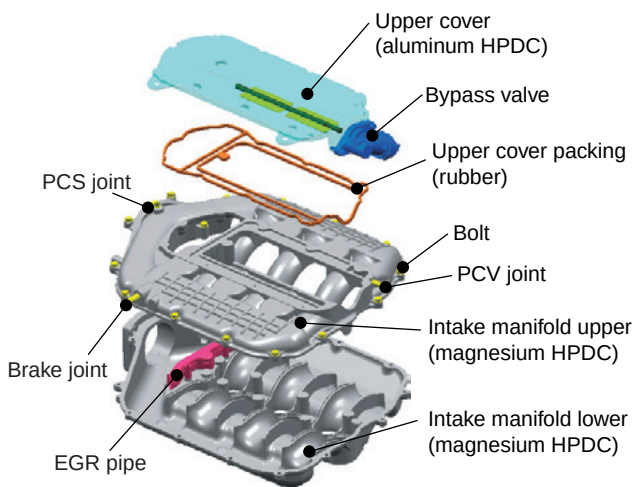


Fig. 1 Structure of magnesium HPDC Intake manifold

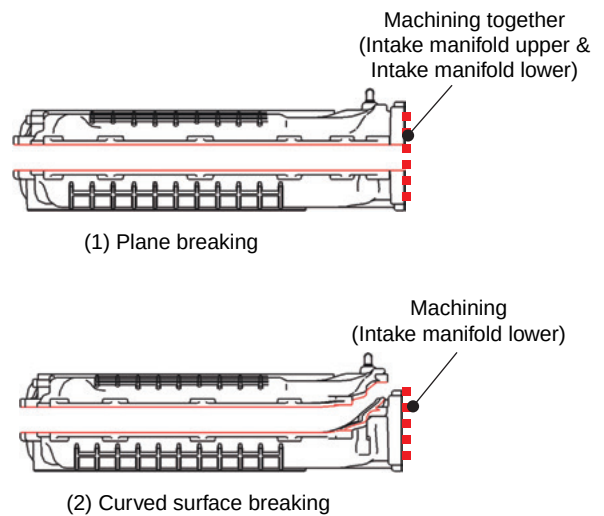


Fig. 4 Breaking pattern

3.3. Seal Structure

The Mg HPDC intake manifold has a FIPG seal between the intake manifold upper and intake manifold lower. In addition, as shown in Fig. 5, the intake manifold has connection surfaces with the fuel injector base, intake port, upper cover, and throttle body. Each connection surface employs the use of a metal gasket, rubber packing, and joint seat to ensure airtight seal within the intake manifold.

3.3.1. FIPG seal area

As shown in Fig. 2, the FIPG seal between the intake manifold upper and intake manifold lower is divided into an outer flange area and port area. There are differences between the outer flange FIPG seal surface and the port area FIPG surface, as shown in Fig. 6.

The outer flange area has a FIPG retention area (circled in Fig. 6), enabling the FIPG to stretch along the sealing surface in reaction to internal pressure changes in the intake manifold. In addition, because the port area does not use bolt tightening, a three-dimensional seal structure was chosen. This allows the seal to be maintained under any deformation condition – vertical, horizontal, and at an angle – due to pressure fluctuations within the intake manifold when the engine is running.

3.3.2. Injector base seal area

The injector base surface uses a metal gasket to ensure an airtight seal between the injector base and the intake manifold. Magnesium alloys have a lower Young's modulus than aluminum alloy, so it is believed that the injector base surface has a lower connection

rigidity. To compensate for this, the gasket seal bead has been changed from a full-bead type to a half-bead type, as shown in Fig. 7. This allows the bead to follow the seal surface movement more precisely and to ensure a seal performance equal to or better than that of the conventional part.

The half-bead type has more than twice the bead restoration ratio (bead height after the compression released / initial bead height) of the full-bead type.

3.3.3. Upper cover seal area

The upper cover surface is sealed with rubber packing material. Low temperature seal performance is ensured by using Fluoro Rubber (FKM) as the rubber packing material. Moreover, the use of a rubber packing material with a left/right symmetrical section, as shown in Fig. 8, provides a shape that will maintain seal performance in the case of any collapse.

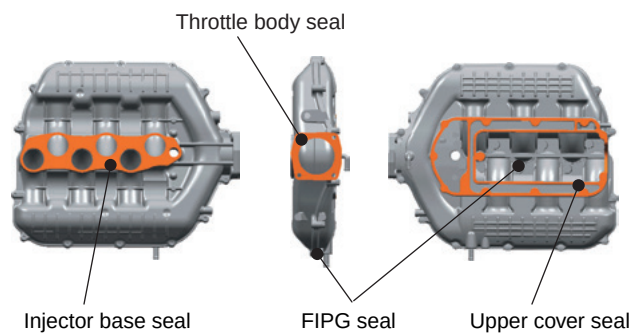


Fig. 5 Seal position

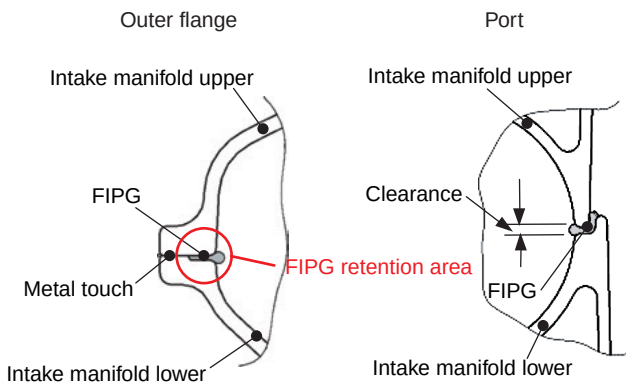


Fig. 6 Structure of FIPG seal plane

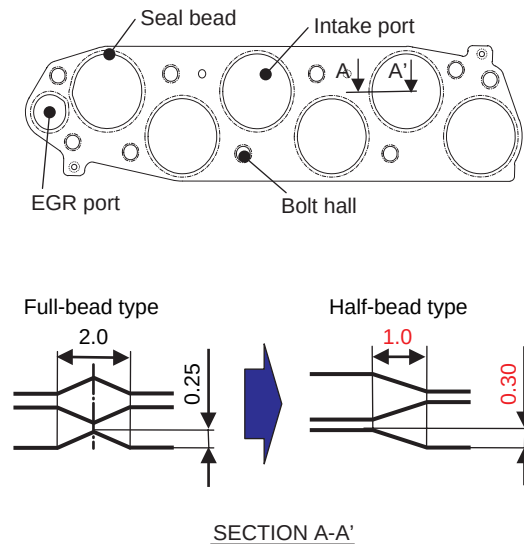


Fig. 7 Appearance and section view of Injector base gasket

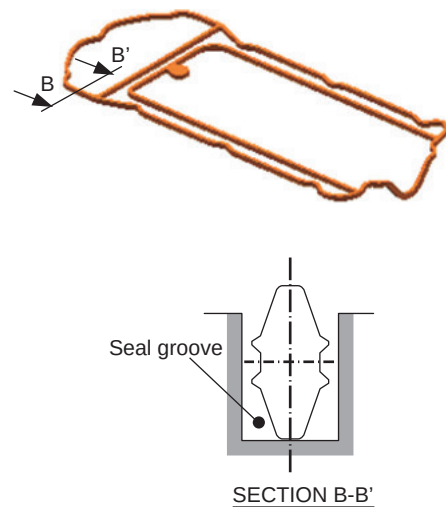


Fig. 8 Appearance and section view of Upper cover packing

3.4. Noise and Vibration Countermeasures

The Mg HPDC intake manifold has a thinner and flatter shape than the AL LPDC intake manifold, so reduced NVH characteristics were expected. From the results of the vibration analysis, surface ribs were added in a grid pattern on the flat areas of the resonance pipe to increase planar rigidity, as shown in Fig. 9. Additionally, connection bolts were added inside the intake manifold, enhancing vibration characteristics on the resonance pipe.

3.5. Resonance Conversion Valve Mechanism

With the conventional Al LPDC intake manifold, multiple hole locations were drilled and a resonance conversion valve was fitted. With the Mg HPDC intake manifold the resonance conversion valve was placed on the intake manifold upper. This is because the joining surface between the intake manifold upper and the intake manifold lower is an as-cast surface where no machining is done. Moving the resonance conversion valve away from the sealing surface avoids applying excessive stress due to flatness inconsistencies on the as-cast surface.

3.6. Corrosion Resistance

The magnesium alloy material AZ91D used for the Mg HPDC intake manifold has corrosion resistance equivalent to the aluminum ADC12 alloy used for the Al HPDC intake manifold. There is no need for coatings to prevent any corrosion. In previous models the intake manifold upper area only was painted, for appearance and commercial appeal.

In addition, as a countermeasure to prevent galvanic corrosion of the bolt connection areas, the same chrome plated bolts as were used on the magnesium HPDC transmission case were adopted.

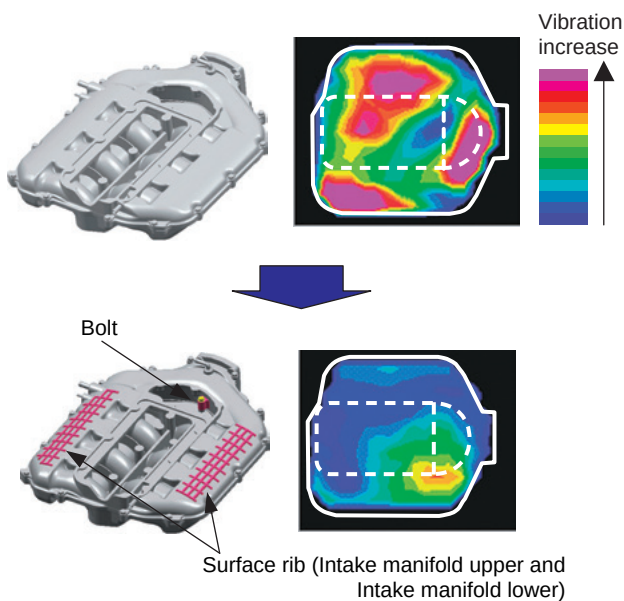


Fig. 9 Effect of surface rib on vibration reduction

4. Magnesium HPDC Casting Technology

In order to create intake manifold dies, casting simulations were carried out, and casting plans established. A high-speed injection type of diecast casting machine was used, and a horizontal layout adopted that enabled a compact casting design.

From the start of the development, a vacuum system was used to enhance molten material flow. The layout of the die heating and cooling circulation lines was established, based on thermal modeling of the inside of the die to obtain a solidification profile.

4.1. Casting Simulations

The solidification time for Mg alloys is shorter than that of aluminum alloy. To reduce the fill time of the castings the magnesium intake manifold upper has a new runner on the side (side gate) as shown in Fig. 10, and a new runner in the space inside the product (bridge). This is different from the runner layout for the Al HPDC intake manifold of the same shape.

The results of the casting simulation showed metal flow that is similar to that of the Al HPDC part. The final area to fill is on the side opposite the sprue, there is no trapped gas, and no areas in the center of the part are the last to solidify.

For the intake manifold lower, as shown in Fig. 11, a bridge was also placed in the center of the part to enhance flow. The results of the casting simulation again showed similar metal flow to the Al HPDC layout. This again confirmed that the final solidification area was on the opposite side from the sprue, there was no trapped gas in the center of the part, and no areas in the center of the part are the final areas to solidify.

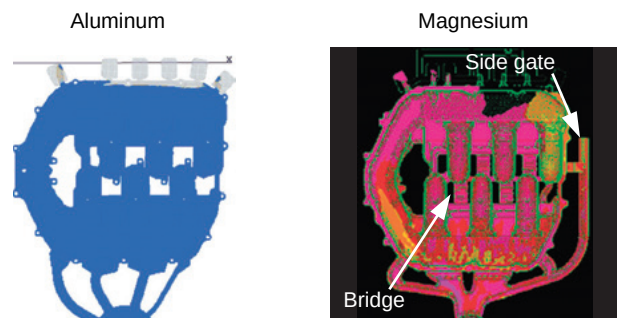


Fig. 10 Simulation of casting of Intake manifold upper

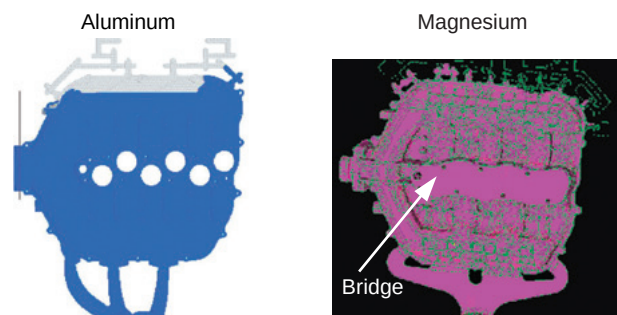


Fig. 11 Simulation of casting of Intake manifold lower

4.2. Setting Casting Conditions

The results of a casting parameter study on prototypes established the final casting conditions.

To prevent the occurrence of shrinkage cavities in the thick areas of the connection boss, Super-Cooling core pin (cooling inside the core pin, combining water cooling and air cooling) were added. The shrinkage cavities, caused by core pin surface overheating, were eliminated from the surface of the thick areas of the connection boss with the Super-Cooling device (circled in Fig. 12).

To ensure clearance between the outer seal surfaces of the intake manifold upper and intake manifold lower, which has a great effect on the outer flange FIPG seal performance, the outer flange flatness as a single part was enhanced by joining the die. Furthermore, to reduce the amount of sealing surface unevenness when removing the sprue after ejection, trim die distortion correction was implemented by clamping the part to the trim die. Increasing the time that the trim die jig holds the outer flange area yields enhanced flatness. As a result, as shown in Fig. 13, enhanced material flatness median values and peak to peak values were achieved.

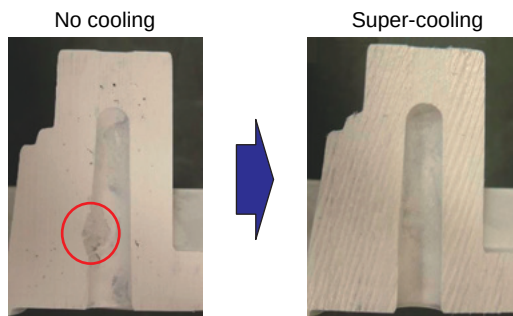


Fig. 12 Effect of Super-cooling

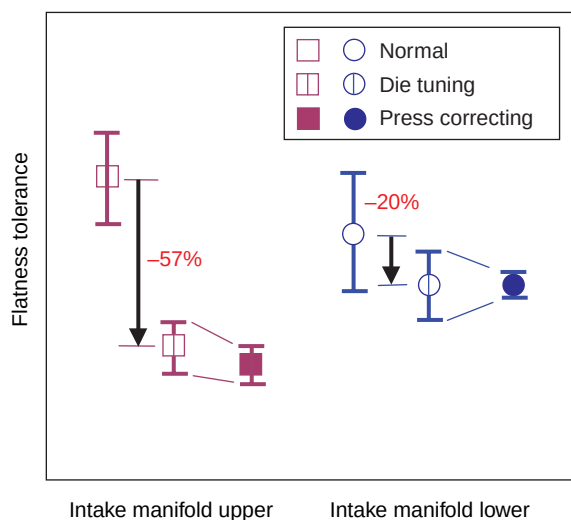


Fig. 13 Flatness of outer flange

5. Weight Reduction Effect

As shown in Fig. 14, the newly developed Mg HPDC intake manifold for the V6 engine is 44% lighter than that of the conventional Al LPDC intake manifold.

Figure 15 shows the appearance of the Mg HPDC intake manifold.

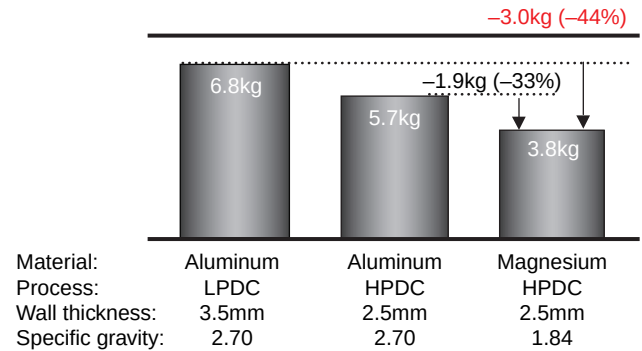


Fig. 14 Comparison of Intake manifold weight

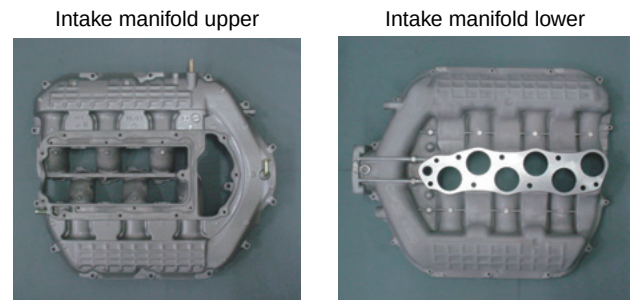


Fig. 15 Appearance of Intake manifold

6. Conclusion

Development of the Mg HPDC intake manifold achieved the following results.

- (1) Three-dimensional seal techniques using Formed-In Place Gaskets, and seal techniques for low rigidity parts using metal gaskets were established.
- (2) Optimizing the shape of low rigidity parts yielded noise and vibration characteristics equivalent to those of mass-produced aluminum LPDC intake manifolds.
- (3) Mg HPDC casting techniques were established for thin walled, large parts, and product quality equivalent to that of Al HPDC intake manifold was achieved.
- (4) Weight reduction of 44% in comparison to the mass-produced Al LPDC intake manifold was achieved.

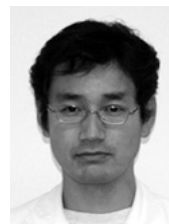
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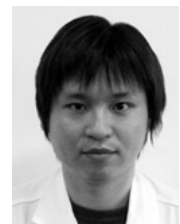
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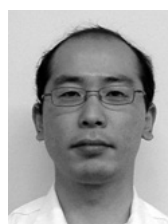
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