Space-saving milling method for bottom surface of cylinder head by utilizing a rotary table

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1.Abstract

With the aims of reducing capital investment, as well as the size and cost of equipment, a new turn milling process has been developed for cylinder block attachment surface of the cylinder head to replace the conventional long-stroke process that used a large cutter. The new process mills the surface with a small cutter while rotating the cylinder head, and achieves a high-quality, flat surface by controlling the rotation speed and feed rate of the cylinder head to create a level machining path density.

2.Details

To ensure the correct pressure between the bottom surface and the gasket, the required machining accuracy for the bottom surface of thecylinder head is the strictest. In addition to surface roughness, waviness, and flatness, no unevenness is permitted. Therefore, conventional machining uses a large cutter with a wider diameter than the short dimension direction (i.e.,the width) of the cylinder head. The large cutter is then moved along the length of the cylinder head, which ensures that no unevenness is generated on the machining surface. When machining using a large cutter, the equioment must capable of holding a heavy tool weighting more than 30 kg, thereby requiring a highly rigid tool clamping structure. The high cutting force created by simultaneous cutting by multiple blades means that the spindle must also be highly rigid. In addition, since the large cutter is moved along the entire length of the cylinder head, a long processing stroke is required. Machines meeting these requirements are extremely large and high-cost. Contouring is a conventional method of machining over a wide range using a compact machine and small cutter. However, it is difficult to satisfy the product accuracy requirements with this method because the cutting load force balance changes between the outward and return legs of the machining path, which tends to result in an uneven surface. In contrast, trochoidal milling is a method that avoids this issue. However, this process requires repeated machining of the same location, requires a long processing stroke, and has a lengthy processing time. These disadvantages have the unwanted effect of increasing the number of machines. The turn milling process was developed to help resolve these issues. In turn milling, the work is rotated and machined to achieve the same effect as trochoidal milling but with a shorter stroke and processing time.

Fig.1 shows a conceptual outline of turn milling process. The cylinder head is rotated on a table and milling is carried out using a small cutter in the direction from the outside toward the center. This enables the whole surface to be machined with a stroke equivalent to half the size of the cylinder head. In addition, unevenness can be eliminated by adjusting the feed rate of the cutter and the rotation speed of the table to ensure that the machining paths overlap. Fig.2 compares the characteristics of the conventional manufacturing process and the turn milling process using a small cutter.

The turn milling process forms the surface by overlapping machining paths using the relative motion of the cylinder head and cutter, resulting in an apparently irregular machining surface such as that produced by a scraping process (Fig. 3). Although surface roughness was a concern due to this irregular appearance, measurements showed that turn milling achieved better roughness than the conventional process and no discernable unevenness. And the surface created by the turn milling process had a smoother profile.

Fig.4 compares the conventional and newly developed manufacturing processes. The top images show the results of simulations for the machining paths of all the cutting blades. The bottom diagrams show enlarged views and cross sections of the machining paths. As described above, the conventional manufacturing process forms the surface roughness by setting machining paths along a circular arc following the rotating motion of the cutter, which have a uniform pitch in accordance with the feed rate. Therefore, the profile of the surface depends on the shape of the cutting edge and the feed rate of the cutter. In contrast, the developed process forms the surface roughness by rotating the cylinder head and overlapping the paths of multiple cutting edges. By repeatedly cutting the same location, the remaining profile peaks are made more uniform, thereby improving the surface roughness. As a result, it was hypothesized that surface roughness with the turn milling process depends on the machining path density, i.e., the number of times that the cutting edges pass over a given location. Considering these results, machining conditions were established to eliminate the difference in surface roughness by speeding up the cutter feed rate from the outer to the center portions of the cylinder head, thereby creating a uniform roughness and shortening the processing time .

3.Conclusion

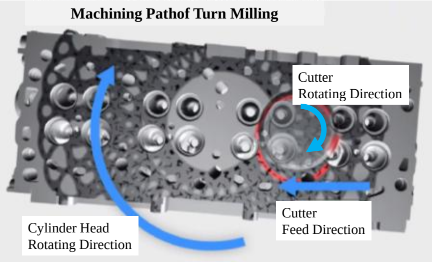
This development combined two existing technologies : milling, in which the tool is rotated, and turning, in which the work is rotated. T he result is a compact and low cost piece of equipment. The next stage is to consider the adoption of this manufacturing method for parts other than the cylinder head, with the aim of helping to simplify and streamline the whole engine machining line.

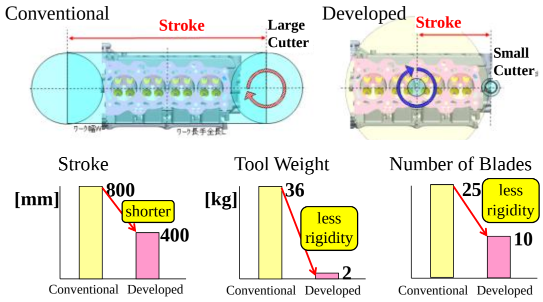
Fig.1 Conceptual Outline of Turn Milling Process

Fig.2 Comparison of the Characteristics

Fig.3 Comparison of Surface Using Conventional and Developed Processes

Fig.4 Surface Roughness Formation Mechanism


Machining Pathof Turn Milling
Cutter
Rotating Direction
Cutter
Feed Direction
Cylinder Head
Rotating Direction


Conventional
Stroke
Large
Cutter
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800
shorter
400
Conventional
Developed
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rigidity
10
Conventional
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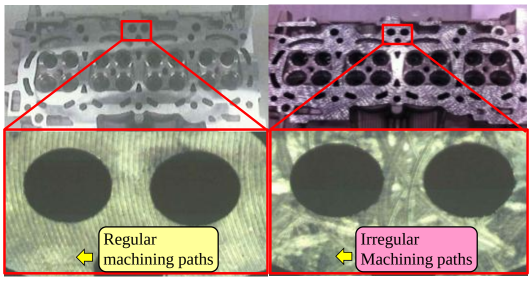
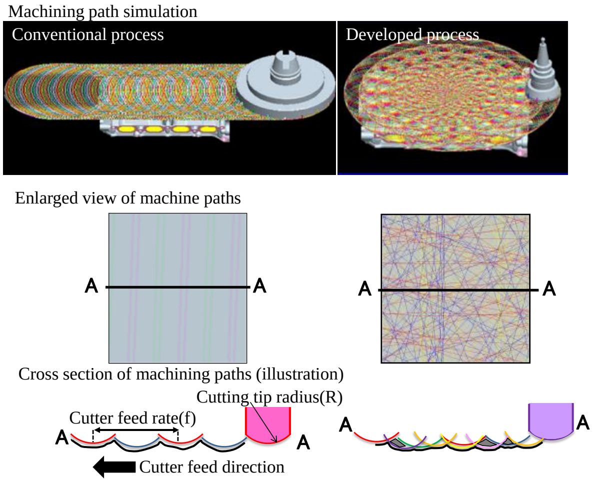

Regular
machining paths
Irregular
Machining paths


Machining path simulation
Conventional process
Developed process
Enlarged view of machine paths
A
A
A
A
Cross section of machining paths (illustration)
Cutting tip radius(R)
Cutter feed rate(f)
A
A
A
A
Cutter feed direction