Features and Machining Examples of μV5 Micro Milling Machine, Capable of Rough Machining

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In recent years, the shapes of parts and molds have become more complex, finer and more precise with the sophistication of functionality and design of industrial products including automotive components. The number of parts requiring a precise fine shape on their surface with size and depth, such as molds for automotive headlights, has been increasing as well. For the machining of such parts, both rough machining ability for forming a shape from a material and high-speed and high-precision machining ability for forming a fine shape are required. In addition, mold materials have become harder and more difficult to cut in order to realize lighter products with higher strength, so the need for high-speed and high-precision spindles has been increasing.

Mitsubishi Heavy Industries Machine Tool Co., Ltd. developed a high-speed and high-precision spindle for the μV1small micro milling machine and have been working on high-speed and high-precision machining using small-diameter tools for the machining of high-hardness and difficult-to-cut materials.

This report introduces features and machining examples of the μV5 micro milling machine, which can handle a wider range of workpiece sizes and has a higher rough machining ability in comparison with the μV1.

1. High-precision machine lineup and major specifications of μV5

Figure 1 shows our high-precision machine lineup including the μV1 small micro milling machine, which is used for palm-sized workpieces, to the MVR-Fx, which is used for large molds such as automobile exterior panels.

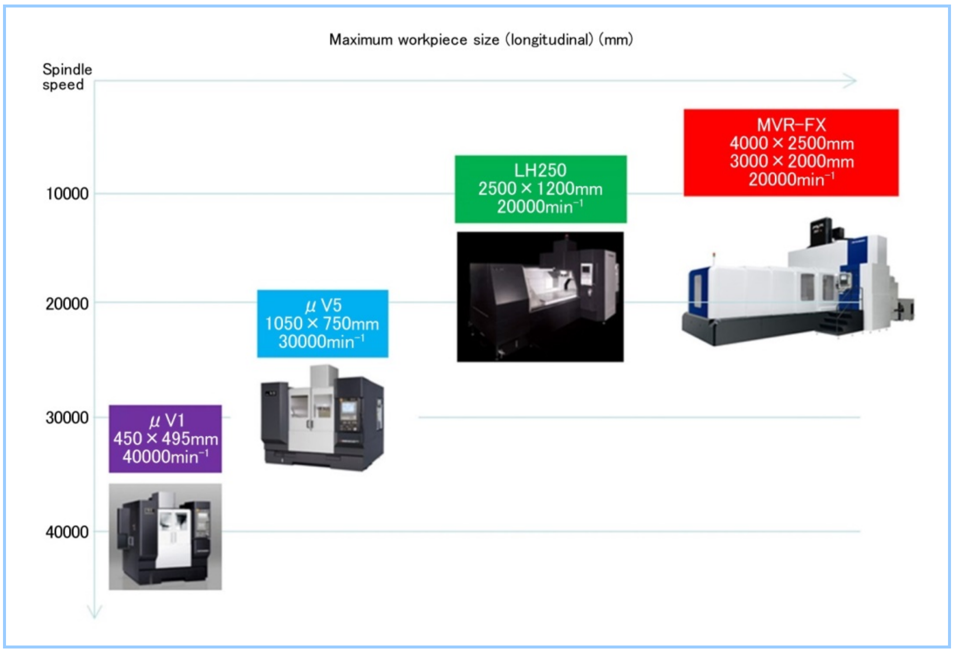


Figure 1 Our high-precision machine lineup

Table 1 shows main specifications of µV5.

Table 1 Main specifications of µV5

Travels	X axis (mm)	900
	Y axis (mm)	550
	Z axis (mm)	450
Table	Working area (mm)	1050×550
	Maximum loading capacity (kg)	800
Spindle	Spindle speed (rpm)	300-30000
	Taper size	HSK-E50
Machine size & mass	Width (mm)	2760
	Depth (mm)	2600
	Height (mm)	2790
	Weight (kg)	12300

2. Features of µV5 micro milling machine

2.1 Machine body

Precise micro machining requires the use of a small-diameter tool. However, because the tool rigidity is limited, it is often the case that machining processes with a very small cutting feed and machining allowance are performed for a long time. For this reason, the machine is required to have such a high dynamic motion accuracy that it can operate accurately without spindle vibration or feeding vibration and that stability during cutting without any thermal displacement of the machine body or the spindle can be ensured.

For the µV5, cooling of not only the outer jacket, which is the casing of the spindle, but also the inside of the spindle rotating at a high speed is adopted. The bearing also uses special jet lubrication, which is our proprietary technique, to forcibly and quickly remove the generated heat. By suppressing the temperature increase of every section of the main shaft, the increase in the bearing preload is eliminated, which allows the maximum suppression of vibration and thermal displacement over the entire range from lower spindle speeds to the maximum spindle speed of 30,000 rpm. In addition, due to the cooling of the inside of the spindle, the initial preload of the bearing can be set high, leading to sufficient rigidity to withstand rough machining.

For the guide surface, a sliding surface that has no vibration source in its mechanism and has a high damping property against external vibration is adopted to suppress the displacement caused by the cutting reaction force.

The machine body has a well-balanced and strong mechanical structure and the heat capacity of the structure is large. Furthermore, a thermally-stabilized column in which a medium with a high heat capacity is enclosed, enhances robustness against environmental temperature fluctuations and other changes.

2.2 Visionplus Tool (optical image type tool measurement system)

Precise micro machining is often performed with a very small cutting feed and machining allowance. For this reason, accurate measurement, positional grasping and correction of the tool tip are also important.

To improve the accuracy of on-machine tool measurement, we independently developed the Visionplus Tool (optical image type tool measurement system) using a high-resolution CCD camera as shown in **Figure 2** and applied this system to the µV5. The Visionplus Tool measures the temporal behavior of the thermal displacement of the machine and tool based on the tool tip position data continuously collected by the camera. It also has a saturation determination function that starts the cutting process after the thermal displacement reaches the set fluctuation range, which enables cutting in a stable area without error.

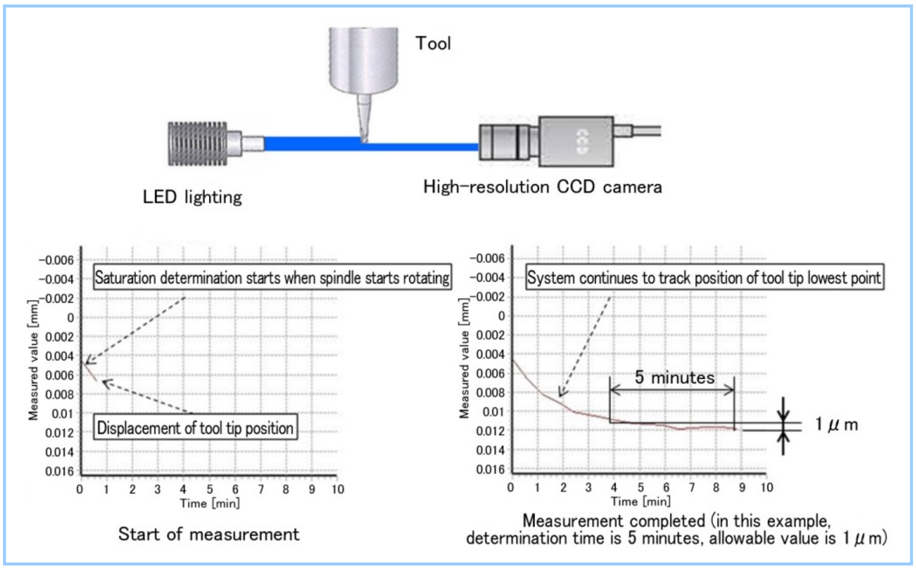
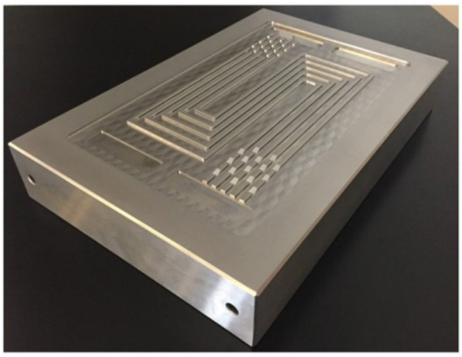


Figure 2　Visionplus Tool (optical image type tool measurement system)

2.3　DIASCOPE (monitoring system)

We are working on the development of DIASCOPE, an IoT platform that supports the optimization of the production activities of our customers (**Figure 3**).

Figure 3　DIASCOPE



Material: STAVAX (52HRC)　Workpiece size: 300 x 200 x 50 mm

Figure 4　Mold sample of fuel cell separator

Currently, we are developing the "Diagnosis/Prediction" phase, and the μV5 is equipped as standard with a remote monitoring system as the "Connecting" function and an operation monitoring system as the "Monitoring" function.

3.　Machining examples

3.1　Mold of fuel cell separator

A mold of a fuel cell separator has grooves over a large area and corners with a small radius. Therefore, the machining of such a mold requires a small-diameter tool and the machining accuracy in the height direction is extremely demanding. **Figure 4** is a photograph of a mold sample workpiece of a fuel cell separator machined by the μV5 and **Table 2** lists the machining conditions.

Although the finish-machining of the groove bottom surface was performed for 23 hours 16minutes using a small-diameter CBN ball end mill with a radius of 0.3 mm at a spindle rotation speed of 30,000 rpm, it required only one tool without any damaging wear. In addition, the machining of the pockets at the four corners was performed for more than 6 hours at a spindle rotation speed of 30,000 rpm, but high-precision machining was realized with a depth accuracy of ±2 μm.

Table 2 Machining conditions for mold sample of fuel cell separator

No	Machining process	Machining type	Tool	Feed rate (mm/min)	Spindle speed (rpm)	Maximum pick (mm)	Machining time
1	Rough machining	Contour line	ϕ 6R0.5 Radius EM	1500	8000	3.0	1 hour 4 minutes
2	Rough machining	Contour line	ϕ 2R0.5 Radius EM	700	12000	1.0	1 hour 40 minutes
3	Pocket semi-finish machining	Contour line	ϕ 6R0.1 Radius EM	1000	8000	3.0	9 minutes
4	Semi-finish machining	Contour line	R0.5 Ball EM	1000	30000	0.05	3 hours 55 minutes
5	External surface finish machining	Contour line	R0.5 Ball EM	800	30000	0.03	1 hour 6 minutes
6	Bottom surface rough machining	Scan line	R1.0 Ball EM	2000	27000	0.2	1 hour 55 minutes
7	Bottom surface semi-finish machining	Scan line	R0.5 Ball EM	1000	30000	0.1	5 hours 50 minutes
8	Rib finish machining	Contour line	R0.3 Ball EM	800	30000	0.03	8 hours 5 minutes
9	Bottom surface finish machining	Scan line	R0.3 Ball EM (CBN)	800	30000	0.03	23 hours 16 minutes
10	Pocket finish machining	Scan line	ϕ 2R0.1 Radius EM	250	30000	0.03	6 hours 41 minutes

Total machining time: 52 hours 41 minutes

3.2 Mold of car air conditioner rear duct

A mold of a car air conditioner rear duct has a relatively large size and depth. **Figure 5** is a photograph of a mold sample workpiece of a car air conditioner rear duct that was formed by rough machining and then finish-machined by the µV5. **Table 3** lists the machining conditions.

Material: NAK0 (40HRC) Workpiece size: 500 x 410 x 150 mm

Figure 5 Mold sample of car air conditioner rear duct

For the rough machining, a φ20R2 high feed cutter was used. Highly-efficient rough machining was achieved despite the use of a high-speed spindle under machining conditions where the spindle speed was 2,870 rpm, the feed rate was 7,000 mm/min and the cutting feed was 10 mm for the XY axes and 0.5 mm for the Z axis.

The product area finish machining was performed for 26 hours 24 minutes using an R3 CBN ball end mill at a spindle rotation speed of 30,000 rpm, but it also required only one tool without any damaging wear. In addition, chamfering machining was performed using an R1.5 ball end mill, but steps from areas machined with the R3 ball end mill could be suppressed due to the optical image type tool measurement system.

Table 3 Machining conditions for mold sample of car air conditioner rear duct

No	Machining process	Machining type	Tool	Feed rate (mm/min)	Spindle speed (rpm)	Maximum pick (mm)	Machining time
1	Very rough machining	Contour line	ϕ 20R2.0 Radius EM	7000	2870	10.0	6 hours 59 minutes
2	Clearance rough machining	Contour line	ϕ 20R1.0 Radius EM	1600	4000	7.0	40 minutes
3	Product area and parting surface rough machining	Contour line	R10 Ball EM	650	1600	2.0	4 hours 46 minutes
4	Parting surface semi-finish machining	Scan line	R8 Ball EM	2000	6000	0.6	2 hours 21 minutes
5	Product area semi-finish machining	Contour line	R8 Ball EM	1000	5000	0.6	5 hours 36 minutes
6	Chamfering rough machining	Chamfering	R6 Ball EM	2800	5200	1.2	42 minutes
7	Chamfering semi-finish machining 1	Chamfering	R3 Ball EM	2000	16000	0.35	1 hour 45 minutes
8	Chamfering semi-finish machining 2	Chamfering	R1.5 Ball EM	2000	30000	0.2	2 hours 16 minutes
9	Product area finish machining	Contour line and scan line	R3 Ball EM (CBN)	3000	30000	0.15	26 hours 24 minutes
10	Chamfering finish machining	Chamfering	R1.5 Ball EM	3000	30000	0.12	1 hour 6 minutes
11	Parting surface finish machining	Scan line	R6 Ball EM	1600	12000	0.22	5 hours 23 minutes

Total machining time: 57 hours 58 minutes

4. Future prospects

This report presented the features and machining examples of the µV5 micro milling machine. We believe that this machine, which can realize highly-efficient rough machining to precise fine-shape finish machining all by itself, will contribute to the improved productivity of our customers. We will continue to advance the sophistication of machinery and peripheral applications for maximizing the performance of tools, while making efforts to contribute to the development of the manufacturing industry.