Development of GC20R-63 CBN Camshaft Multi-Task Grinder

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We have developed a CBN camshaft multi-task grinder, the GC20R-63, equipped with an automatic wheelhead swiveling unit. It automatically changes two types of grinding wheels to enable optimum grinding and process integration for each machined portion of the target workpiece and also uses a high output, small diameter wheel spindle to achieve the high efficiency grinding of concave cams.

***Key Words**: camshaft, wheelhead swiveling, process integration, concave cam*

1. Introduction

In recent years, the automotive industry has been swept by a wave of fuel economy and low cost demands and all automakers have released ambitiously new products on the market one after another. Electric vehicles (EV) and hybrid vehicles (HV) are particularly attracting attention. However, engine-mounted automobiles still hold the majority. Due to the diversification of customers' demands, the lifecycle of automobiles has been becoming shorter and flexible approaches are required in production sites. To achieve low cost, production in highly in-demand countries such as China and India has increased. To achieve fuel economy, efforts are being made towards downsizing and increased efficiency. For improving engine performance, improvements have been made in valve operating systems and, consequently, camshafts have made notable strides compared to other engine components.

Fig. 1 GC20R-63 CBN Camshaft Multi-Task Grinder

Production lines now need to be flexible due to the increase in overseas production and shortened product lifecycle, and, in response, have become more universal to allow multi-variety workpiece production and adopt a process integration approach to achieve downsizing. In addition, as a means for improving fuel economy, a valve-driven roller rocker arm has been adopted for valve systems, and there is growing demand for adopting concave cams in the name of further increasing efficiency. The GC20R-63 CBN Camshaft Multi-Task Grinder introduced in this report has been developed to meet such customer demands (**Fig. 1**).

2. Development Aims

JTEKT began marketing the GC20M-63 CBN camshaft grinder in 2005 under the concept of optimum equipment to suit the workpiece and has been rewarded a high reputation in the market[1].

The GC20R-63 is based on the GC20M-63 and, by equipping an automatic wheelhead swiveling mechanism to the GC20M-63, the GC20R-63 can switch wheels and perform optimum grinding for each portion machined, making it possible to reduce the number of machines through process integration.

2. 1 Technical Background of Camshaft

Requirements of a camshaft from the viewpoint of fuel economy are summarized in **Table 1**.

Table 1 Fuel efficiency technology in valve systems

Fuel efficiency improvement method	Approach taken in valve system	Camshaft requirements
Reduction of frictional loss	Roller rocker arm	Adoption of FCD
Improved intake and exhaust efficiency	Increased valve opening time area	Adoption of concave cam
	Variable valve timing and lift mechanism	Adjacency of switching cams
Combustion control	Direct fuel injection inside cylinder	Adjacency of pump cams
Downsizing	Adoption of SOHC	Adjacency of intake and exhaust cams

To reduce friction loss, use of a roller rocker arm with a roller follower in the valve drive is becoming more wide-spread and, as the cam material requires resistance against abrasion and pitting, the ratio of spheroidal graphite cast iron (FCD) has increased. In addition, the demand for concave cams is growing to expand the valve opening time area in order to improve intake and exhaust efficiency.

For the variable valve timing and lift mechanism, as the method of switching cams becomes mainstream, different profiles of cams are arranged adjacent to the camshaft. As such, pump cams are becoming necessary as the power source for direct fuel injection into the cylinders.

2. 2 Camshaft Grinding Example

This section introduces what the GC20R-63 offers for the purpose of satisfying camshaft requirements **(Fig. 2)**.

2. 2. 1 FCD

Compared to conventional chill casting materials, FCD generates a large amount of heat during grinding and is highly susceptible to the microstructural change caused by grinding heat. For this reason, it is difficult to improve the grinding efficiency of FCD. The amount of stock removal increases due to quenching prior to machining, standardization of materials among different kinds of engines, and so on. Consequently, the grinding process has been divided into rough grinding and finish grinding, and wheel specifications and conditions for rough grinding have been separately established to enable reduction of tool cost in small-scale production.

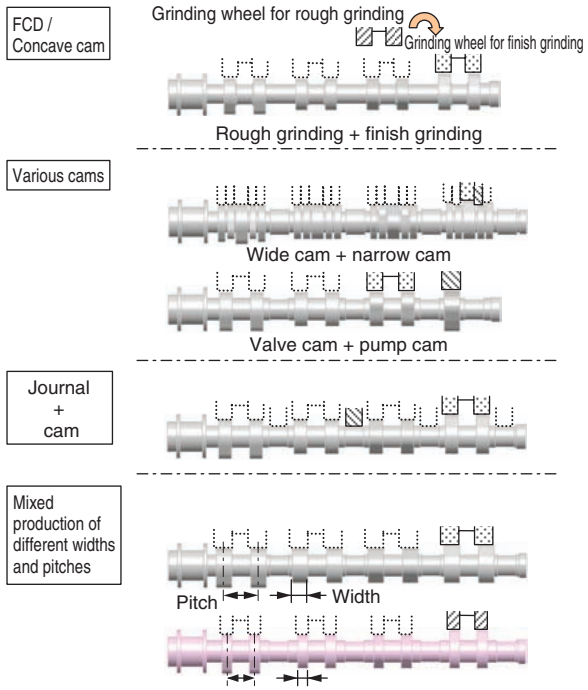

Fig. 2 Grinding examples

2. 2. 2 Concave Cam

Using a small diameter wheel for rough grinding concave cams and grinding the finish profile can reduce finish stock removal **(Fig. 3)**. On the GC20R-63, by using a wheel spindle tailored for a high output, small wheel for both rough grinding and finish grinding, the two processes can be integrated. Furthermore, by adopting a newly developed long-life, small-diameter wheel for rough grinding, tool cost has been reduced **(Fig. 4)**.

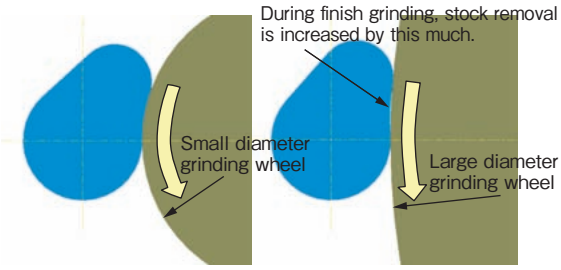

Fig. 3 Influence of wheel diameter on stock removal

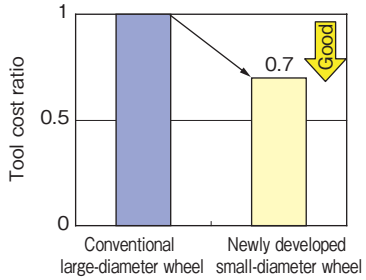

Fig. 4 Tool cost of newly developed wheel

2. 2. 3 Process Integration of Various Cams

In the process integration of variable valve timing and the lift mechanism switchover cams, valve driven cams, pump cams, etc., switching wheels can avoid interference caused by differing cam widths, etc.

2. 2. 4 Process Integration of the Cam and Journal

On the GC20R-63, not only various cam combinations, but also switching wheels can integrate cam and journal processes with different widths.

2. 2. 5 Process Integration in the Initial Stage of Large-Scale Line Startup

It sometimes takes several years for large-scale lines to build up from small quantity production at the time of production startup to full capacity. By integrating processes, plant costs prior to full capacity production can be suppressed.

2. 2. 6 Mixed Production of Camshafts

The GC20R-63, for the sake of line standardization, is designed to better respond to differences in cam width and pitch using wheel changeover.

3. Machine Features

3. 1 Automatic Swivel of the Wheelhead

Wheels are switched through the automatic swivel of the wheelhead. A motor direct drive system is used as the wheelhead swivel driving system for increased speed. In addition, highly accurate reproduction and high rigidity are achieved by adopting a highly rigid coupling. Due to this, a swiveling position accuracy of ± 0.001° and swiveling speed of 3s/180° are achieved **(Fig. 5)**.

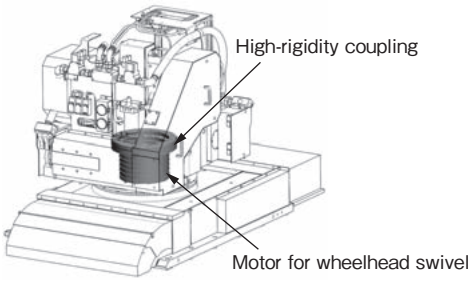

Fig. 5 Structure of wheelhead swivel unit

3. 2 Wheel Spindle Unit

To respond to the high efficiency grinding of concave cams, we have developed a high output wheel spindle unit for small diameter wheels. This unit adopts the TOYODA STAT BEARING® which is highly-reputed for its high accuracy and high reliability, achieving an output with a ϕ120 small diameter wheel of 30 kW, which is about 3 times that of the conventional one **(Fig. 6)**.

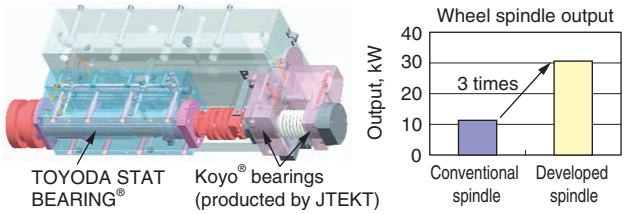

Fig. 6 Structure of wheel spindle unit for small diameter wheel

3. 3 Wheelhead Feed Unit

By adopting the same drive that has been proven on the GC20M-63, which uses a hydrostatic slideway and linear motor drive, high-speed, high-accuracy and high-rigidity feed has been achieved.

3. 4 Spindle Variable Speed Control

In order to perform high accuracy speed change, a motor direct drive system has been adopted for the workhead drive. In cam profile grinding, spindle variable speed control is used to maintain the stock removal rate at the maximum level throughout one cam rotation. As a result, grinding resistance is equalized, profile accuracy is improved, and cycle time is shortened all at the same time **(Fig. 7)**.

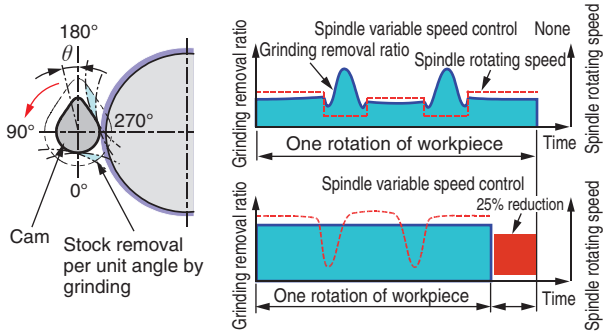

Fig. 7 Spindle variable speed control

3. 5 Isolation Cover

Rise in the temperature of the bed is a significant factor of thermal displacement in a grinding machine. As a measure to reduce thermal displacement, an isolation cover method is used to prevent coolant heated by grinding from splashing directly on the bed **(Fig. 8)**.

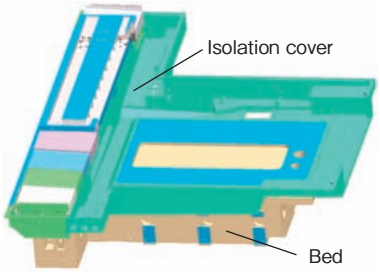

Fig. 8 Isolation cover

4. Main Specifications

Table 2 shows the main specifications of the GC20R-63.

Table 2 Main specifications

[ ] Option

Item		Unit	GC20R-63
Swing over table		mm	ϕ320
Distance between centers		mm	630
Grinding diameter		mm	ϕ20~ϕ300
CBN wheel	Bearing type	–	TOYODA STAT BEARING®
	Outer diameter (OD)	mm	ϕ350 [ϕ120]
	Max. width	mm	40 (Multi 20 + 20)
	Surface speed	m/s	120 [80]
Wheelhead	Feed method	–	Hydrostatic slideway, Linear motor drive
	Rapid feed rate	m/min	ϕ40
	Min. input imcrement	mm	ϕ0.0001
Wheelhead swivel unit	Swivel method	–	DD motor
	Swivel angle	degree	180 (2 positions)
Table traverse feed	Feed method	–	V-flat slideway, Ball screw drive
	Rapid feed rate	m/min	20
	Min. input increment	mm	0.0001
Workhead	Type	–	Rotating spindle workhead
	Center	–	MT No.4
	Max. spindle speed	min^{-1}	250
	Min. input increment	degree	0.0001
Footstock	Type	–	Hydraulic
	Center	–	MT No. 4 [MT No. 3]
Electric Motor	Wheel spindle	kW	30
	Wheelhead feed	kW	9.8
	Wheelhead swivel	kW	2.4
	Table traverse feed	kW	2.6
	Spindle	kW	2.5 (Built-in motor)
	Truing roll	kW	0.75
	Pump for wheel spindle bearing	kW	3.7 (4P) ×2
	Hydraulic oil pump	kW	0.75 (4P)
	Lubrication pump	kW	0.4 (4P)
Power supply voltage		V	200
Tank capacity	Spindle bearing lubricant	L	150
	Hydraulic oil	L	20
	Lubricating oil	L	40
Net weight		kg	13 000

5. Machine Layout

Figure 9 shows the standard machine layout.

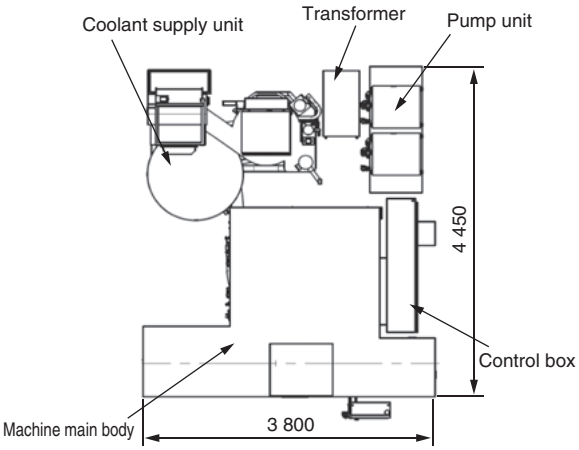

Fig. 9 Standard machine layout

6. Conclusion

The GC20R-63 CBN Camshaft Multi-Task Grinder has been developed for the purpose of process integration in the camshaft grinding process. JTEKT has introduced the GC20M-63, etc., to the market at an appropriate time and offers them to customers. JTEKT hopes to continue to provide customers with better proposals and develop further products into the future.

Reference

1) S. Yamaguchi: GC20M-63 Camshaft Grinder, Toyoda Koki Giho (Toyoda Koki Technical Review), 46, 2 (2005) 8.

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