New Guideless CNC Shaper for Helical Gears

Kenji Ueno

Product announcements so often trumpet minor, incremental advances with words like "revolutionary" and "unique" that even the best thesaurus can fail to offer a fresh alternative to alert the reader when something really innovative and important is introduced. In the case of Mitsubishi's new CNC gear shaper, the ST25CNC, both terms apply.

The ST25CNC (Fig. 1) eliminates the need for expensive helical guides that cost several thousand dollars for each gear size and lead change. Changeover on this machine requires only reprogramming the CNC to cut each new configuration, unlike older machines that require several hours to set up a new guide set. Windows®-based, user-friendly CNC controls with a touch screen feature make custom programming easier and eliminate lengthy programming time. This combination of lower cost, simplified changeover and streamlined programming means that gear designers can now experiment with new refinements in order to provide the most efficient power transfer components.

Engineers at MHI Machine Tool U.S.A., Inc., Itasca, IL—a subsidiary of Mitsubishi Heavy Industries America, Inc.—believe that this new flexibility will be the reason the innovative ST25CNC shaper will be adopted by initial users. S. Amano, President of MHI Machine Tool, reports that a major automotive company in Japan has already placed an order for the new shaper.

The Impetus for Innovation

One strong impetus behind Mitsubishi's investment in the ST25CNC has been vehicle downsizing, which has created the need for smaller transmission gears. Smaller gears have less contact area, which translates directly into lower strengths. To increase contact area and strength at a given gear diameter, designers have increased the helical angle. The 25° angle that was once common has given way to helical angles that are now often more than 35°.

When an internal gear is manufactured, gear shapers are generally used. As shown in Fig. 2, in this machining method, the cutter and workpiece are turned synchronously and the cutter reciprocates axially. In the case of helical gears, because helical motion is matched to the cutter lead, a helical guide is used. When the cutter lead is different, the helical guide must be changed.

The NC Guide Drive Principle

In helical gear machining using a gear shaper, the relationship between workpiece helical angle β and cutter lead H is given by the formula below.

$$H = \frac{\pi dc}{\tan\beta}$$

where β is the workpiece helical angle, H is the cutter lead length and dc is the cutter pitch circle diameter.

In Fig. 3, the design of a conventional shaper (a) is contrasted to that of the new ST25CNC (b). In the latter, the male and female helical guides are absent. In the Mitsubishi design, reciprocating and

Fig. 1 — Mitsubishi Flexible Gear Shaper ST25CNC

THE ST25CNC'S CONTROLLER OPERATES AT MUCH HIGHER SPEEDS THAN THOSE ON CONVENTIONAL MODELS.

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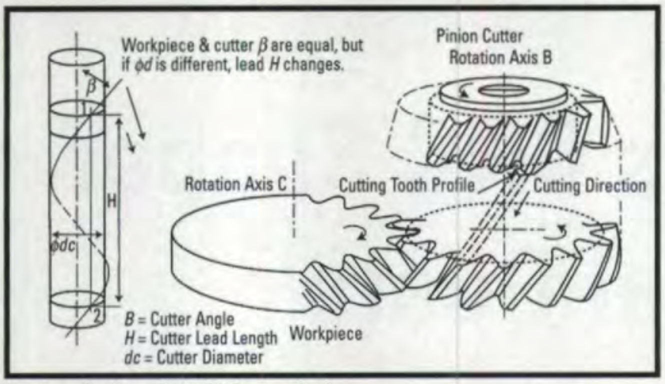


Fig. 2 — Outline of machining method.

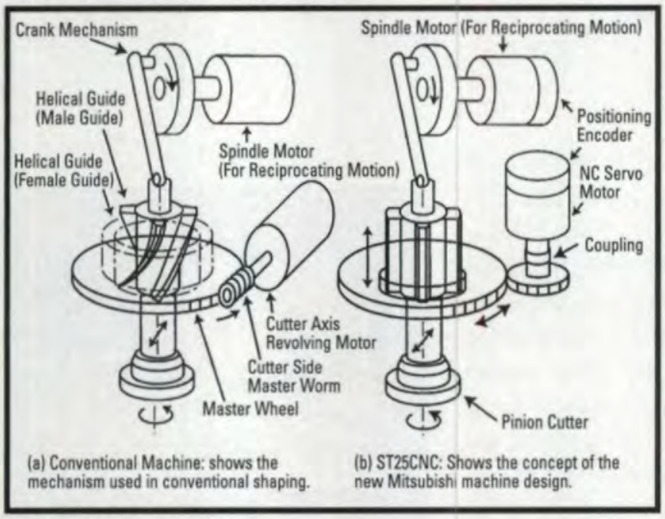


Fig. 3 — Guide mechanism.

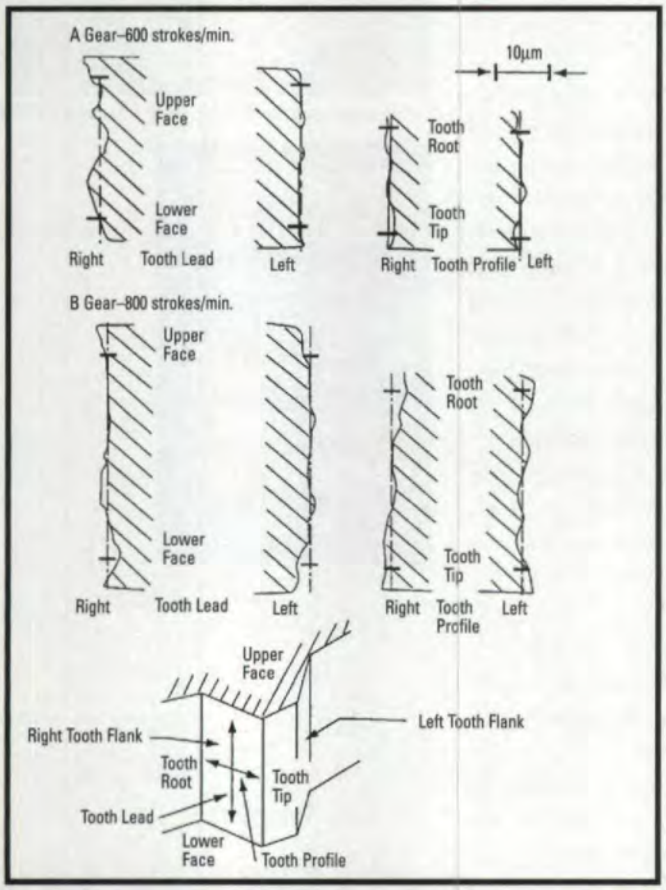


Fig. 4 — Accuracy achieved: AGMA 10 data points obtained from measuring gears cut on ST25CNC according to cutting conditions shown in Table 2.

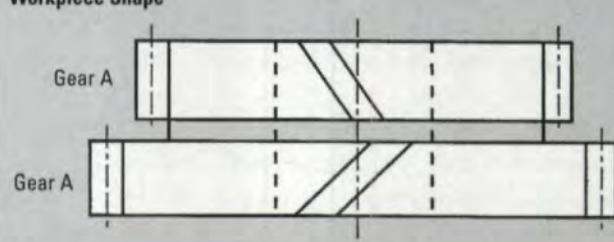
TABLE 1 — MAJOR SPECIFICATIONS

Maximum Helical Angle	±36°
Workpiece Maximum Diameter:	
External Gear	250 mm
Internal Gear	120 mm + cutter diameter
Maximum Module	6
Maximum Machining Face Width	50 mm
Number of Spindle Strokes	200–1000 strokes/mm
Circumferential Feed Rate	5000 mm/min
Radial Cutting Feed	1000 mm/min
Radial Rapid Traverse Rate	10000 mm/min
Radial Travel	300 mm
Number of Passes	1–4 times
Cutter Spindle Diameter	100 mm
Table Diameter	330 mm
Main Motor Output	10 kW AC servo
Machine Weight	6500 kg
Floor Space	2325 x 2775 mm
Machine Total Electric Power	35 kVA

TABLE 2 — GEAR SPECIFICATIONS AND CUTTING CONDITIONS

Item	Dimension	Gear A	Gear B
Workpiece Dimensions	Module	1.75	2.25
	Helical Angle (°)	30	25
	Helical Direction	LH	RH
	Number of Teeth	23	23
	Face Width (mm)	10	15
	Outer Diameter (mm)	44.471	61.6
Cutter Dimensions	Outer Diameter (mm) Number of Teeth	115 54	150.7 58
Machining Conditions	Number of Strokes (strokes/mm)	600/600	800/800
	Circumferential Feed (strokes/mm)	1.5/1.5	1.58/1.58
	Radial Feed (mm/stroke)	0.01/0.006	0.01/0.006
	Cycle Time(s)	57	55

Workpiece Shape



oscillating motion are synchronously controlled by the CNC.

A Faster, Smarter CNC

To synchronously control three axes and produce gears with accuracies of higher than AGMA 10, for example, it was necessary for the CNC to operate at much higher speeds on the ST25CNC gear shaper than on its conventional predecessor, the SD25CNC. Simulation studies revealed that data transmission speeds on the order of under 1 ms would be required, in contrast to the 8 ms speed that was typical of the conventional system.

The ST25CNC's high-speed feed control focuses on extreme accuracy. Using a modified, inverse-transfer function data processing method, with virtually zero servo error, the system reads the NC data in advance of the servo amplifier to compensate for under- or over-torque at the same point in the next stroke. Again, enhanced accuracy is the result.

In Tables 1 and 2, major machine specifications and representative gear specifications and cutting conditions are given. In the example shown in Table 2, a two-stepped cutter with different helix angles was used to machine the workpiece in one chucking. Fig. 4 demonstrates the machining accuracy realized at 600 strokes/min for Gear A and 800 strokes/min for Gear B. This setup could not be done on a conventional machine. It is now possible to cut Gears A and B in setup times of less than 5 minutes.

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THE MACHINE USES SYNCHRONOUS, CNC-CONTROLLED RECIPROCAL AND OSCILLATING MOTION TO GET GREAT FLEXIBILITY AND MORE MANUFACTURING SPEED.