High-Efficiency Cutter for Aluminum Alloys Machining “ALNEX ANX Series”

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In automobile-related industries, the use of aluminum alloy and other nonferrous metal parts has been increasing to reduce the weight of vehicles for improved fuel efficiency and to respond to the increasing production of hybrid vehicles, electric vehicles, and fuel cell vehicles. To increase the productivity in machining of these parts, cutting tools are required to be easy to handle and highly effective in chip control, for reducing machining time and no-machining time. Furthermore, there is also a growing demand for lighter cutting tools suitable for compact machining equipment to improve the productivity per unit area of machining equipment. To meet these demands, Sumitomo Electric Industries, Ltd. has developed a polycrystalline sintered diamond (PCD) cutter, ALNEX (ANX Series), for high-efficiency machining of aluminum alloys. This paper describes the features of the new cutter.

Keywords: PCD (polycrystalline sintered diamond), aluminum, high efficiency, cutter, chip control

1. Introduction

One recent trend in the automotive industry is the growing demand for improved fuel economy. In line with this trend to reduce the weight of automobiles, aluminum alloys with low specific gravity and high strength are being used in an increasing number of automotive parts. Meanwhile for improved productivity, production sites that finish aluminum alloys are required to improve their machining efficiency, use low-unit-cost tools, and reduce non-cutting time. In addition, cutting produces a large amount of chips, which causes various serious problems. Accordingly, tools that solve these problems are in demand. To fulfill all of these needs at once, Sumitomo Electric Industries, Ltd. has established a novel manufacturing process and developed machining tools with proprietary design and improved functionality. This paper describes the features of the newly developed ALNEX (ANX Series) (Photo 1) and machining examples.

Photo 1. ALNEX (ANX Series)

2. Features of ALNEX (ANX Series)

2-1 Ultra-high speed and high-efficiency machining

The ALNEX (ANX Series) incorporates Sumitomo Electric’s original blades. These blades are smaller than those of the conventional blades. Moreover, the number of cutter parts has been drastically reduced to enable an ultra-multi-blade design, i.e., 4.5 blades per inch, with the number of blades 1.5 times greater than that of the conventional design. The current 100 mm diameter cutter has 18 blades. Furthermore, special geometry used to clamp blades, a high-strength body design, and blade weight reduction have been simultaneously achieved to successfully keep the blades from flying off and the edges from being displaced due to centrifugal forces during high-speed rotation. Consequently, the 100 mm diameter cutter machines at a maximum rotational speed of 18,000 revolutions per minute (rpm). The benefits gained by combining these features are machining efficiency of 30,000 mm/min or more even at a tool feed rate of 0.1 mm/t, as illustrated in Fig. 1, and high-precision, stable, and long-life machining even under high-efficiency machining conditions.

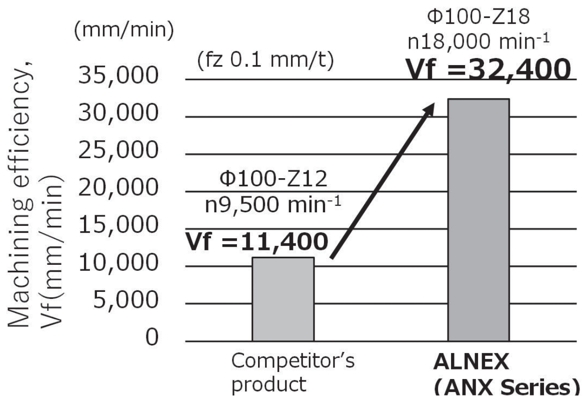


Fig. 1. Machining efficiency

2-2 Enhanced ease of operation

For stable machining and long life, it is recommended that polycrystalline sintered diamond (PCD)*[1] cutters with PCD are adjusted with a high precision of 5 µm or less in edge height variation. Some conventional cutters incorporate a wedge-style edge-runout adjuster. These are structured to clamp each PCD-edged blade between a wedge and the cutter body (Photo 2). This style is subject to substantial strain in the body that is produced when tightening the wedge, resulting in a large variation in edge height. The strain produced throughout the entire body necessitates repeated edge height adjustments. Meanwhile, an increased number of blades mounted on the cutter body translate to an extended length of time required for blade replacement and edge runout adjustments. Additionally, the resulting smaller pockets tend to hamper ease of operation during work.

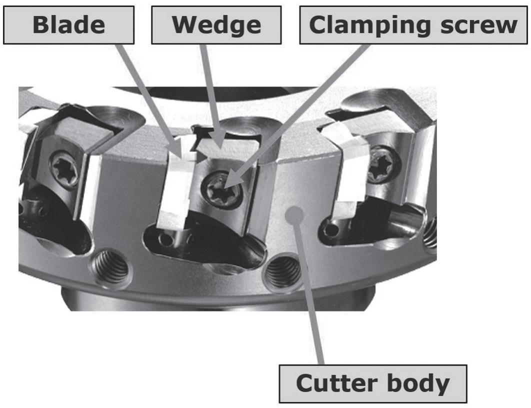


Photo 2. Wedge-style cutter structure

The ALNEX (ANX Series) features a newly developed simple clamp mechanism and Sumitomo Electric's proprietary fastening method. These features suppress body deformation during clamping to minimize changes in edge positions while maintaining a strong force to clamp the blades to the body. Moreover, improvements have also been made to the conventional method used to adjust edge heights. Edge heights are adjusted with an adjusting wrench. The wrench is inserted into a hole in the adjusting screw and turned right or left. Since the conventional body structure has this hole in a confined location, it is difficult to locate the hole in the screw insufficient lighting work environment. As a solution to this challenge, we structured the body to have a slit in it, as depicted in Fig. 2. This structure allows the operator to easily locate the hole in the screw at every possible line-of-sight angle and to insert a wrench into it with ease. In addition, the movable range of the wrench was expanded to 160°, about twice that of the conventional structure. This means an increased amount of edge height adjustment in a single wrench operation. It has thus become easy to make height adjustments even when requiring a large amount of edge projection, such as that needed for a re-sharpened cutter with a shorter overall length. Provided with these developments, the ALNEX (ANX) allows the operator to adjust edge heights in a single operation of edge runout adjustment, as shown in Fig. 3. Consequently, although the number of edges has increased to 1.5 times the conventional design, the multi-blade design has successfully and substantially reduced the edge runout adjustment time by half compared with that of the conventional design.

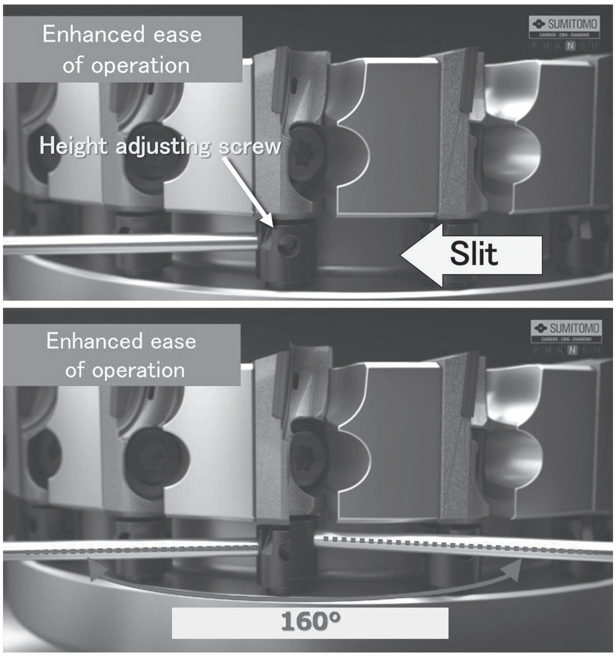


Fig. 2. Improved height adjustment

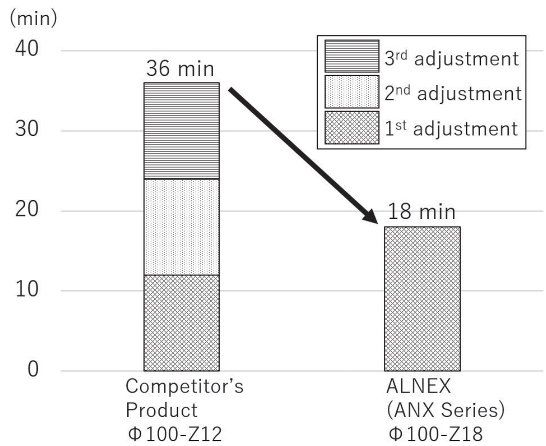


Fig. 3. Time required for edge runout adjustment (5 µm or less)

2-3 Improved chip control

For the ALNEX (ANX Series), we have successfully developed a blade that offers two major capabilities by adopting a newly developed carbide forming technology. One capability is the breaking of chips using a coolant flowing through the blade. When machining an aluminum alloy, long chips are produced, causing problems to workpieces and equipment. At the machining site, it has been desired to reduce the chip length to 3 mm or less. However, conventional products mostly discharge coolant from the cutter body directly to edges. PCD cutters designed for aluminum alloy machining predominantly operate at a high rotational speed. Because of the long distance between the coolant discharge port and the end of the machine, most of the discharged coolant is scattered outward immediately after discharge due to centrifugal force. Consequently, the coolant does not reach the edge , failing to achieve the goal of reducing the chip length to 3 mm or less. To address this issue, Sumitomo Electric strived to work out an ideal structural design for discharging coolant and decided to open a discharge port in the blade as it was closest to the edge for discharging the coolant. The coolant fed from the cutter body flows through the blade and is discharged as close to the edge as feasible, as shown in Photo 3. It thus became possible to feed the coolant reliably to the edge, while maintaining its high pressure stably even at a high rotational speed. Therefore, chips are severed into short pieces, as pictured in Photo 4. This capability reduces the entanglement of chips and facilitates chip evacuation from the workpiece, mitigating workpiece and equipment problems. Long chips caught by edges shortens the life of a tool. Regarding this machining problem, the new design that controls the catching of chips helps extend the tool life.

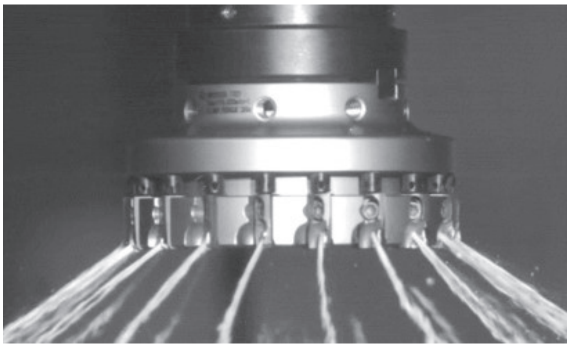


Photo 3. Discharged coolant

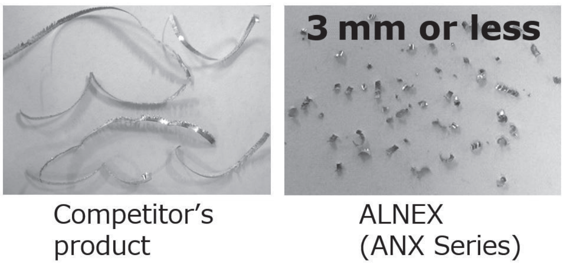


Photo 4. Comparison of chips

The other capability features chip pockets designed to mitigate damage to the cutter body and control the chip evacuation direction. Conventional cutters evacuate chips at a high speed, which abrades the cutter body and other parts made of steel or aluminum alloy, accelerating the wear of these parts and reducing the life of the cutter body. However, the ALNEX (ANX Series) controls chips to abrade blades, unlike the conventional design, in which chips freely abrade the cutter body, as shown in Fig. 4. Chip pockets are provided in the abraded area and the base material of blades is made of carbide. These ideas have led to substantially reduced wear caused by chips and a prolonged life for the cutter body. Moreover, the chip pockets are ideally designed to guide chips outward to evacuate the chips—otherwise flying in every direction in the conventional design—in a constant direction, as illustrated in Fig. 5. This design is effective in mitigating various problems caused by chips in machining equipment.

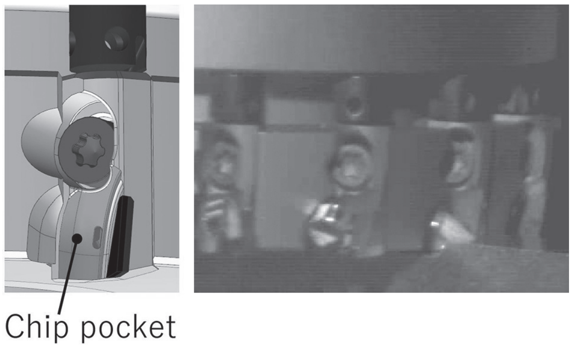


Fig. 4. Body damage mitigation

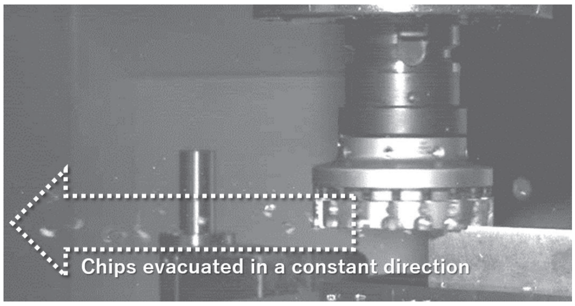


Fig. 5. Controlled chip evacuation direction

3. Application examples

Table 1 presents an example of machining of automotive parts made of an aluminum alloy in a small machining center (M/C) with the BT30. The BT30 efficiently machined with 22 blades mounted on merely a 125 mm diameter tool. The cutter body, made of an aluminum alloy, weighed only 1.75 kg including an arbor. Its high-speed rotation and multi-blade design quadrupled the level of efficiency compared with a product from one of Sumitomo Electric's competitors. The tool's enhanced ease of operation helped substantially reduce the non-cutting time. Moreover, the edges of the ALNEX (ANX Series) were Sumitomo Electric's PCD grade Sumidia DA1000, featuring exceptional toughness and superb wear resistance. In contrast to the competitor's product, which exhibited early edge chipping, the ALNEX (ANX Series) was free of edge chipping, machined stably, and demonstrated an increase in tool life by a factor of 11.

Table 2 provides an example of machining of automotive parts made of aluminum alloy using a small-diameter (25 mm) shank-equipped tool. The competitor's product was a brazed PCD tool. Both tools were operated using the same number of edges and machining efficiency conditions. However, for re-sharpening of the tool after use, the competitor's brazed tool needed to be sent in its entirety to a re-sharpening service provider, necessitating the provision of more tools than would otherwise be required. Moreover, if, for example, one of the two blades were seriously damaged, the brazed tool would not be able to be re-sharpened and would have to be discarded.

On the other hand, the ALNEX (ANX Series), using indexable inserts, required only the blades to be sent for re-sharpening. Even if one blade was seriously damaged, the other blade could be reused through re-sharpening, contributing to a substantial tool cost reduction. Furthermore, the ALNEX (ANX Series) enables the blade model to be easily replaced according to the worksite's specific machining needs. It is thus well-received in terms of ease of tool handling.

Table 1. Example Machining 1

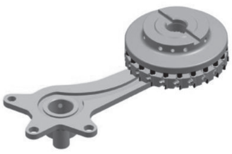
Automotive Component(ADC12)		ALNEX	Competitor's
Vertical Machining Cenrter	Tool	ANXA16125R22	PCD Cutter
BT30	Grade	DA1000	-
	Blade	ANB1600R-H	-
	Tool Dia. (mm)	125	125
	No. of tooth	22	6
	Vc (m/min)	3,142	3,142
	Vf (mm/min)	14,080	3,520
	fz (mm/t)	0.08	0.073
	ap (mm)	0.8	0.8
	ae (mm)	-	-
	Coolant	WET(Internal)	WET(External)
	Results	4 times efficiency and 11 times the tool life	

Table 2. Example Machining 2

Automotive Component(ADC12)		ALNEX	Competitor's
Vertical Machining Cenrter	Tool	ANXS16025E02	Brazed
BT30	Grade	DA1000	PCD
	Blade	ANB1604R	-
	Tool Dia. (mm)	25	25
	No. of tooth	2	2
	Vc (m/min)	471	471
	Vf (mm/min)	900	900
	fz (mm/t)	0.075	0.075
	ap (mm)	0.3～1.5	0.3～1.5
	ae (mm)	7～10mm	7～10mm
	Coolant	WET(Internal)	WET(External)
	Results	Chips severed into short pieces owing to internal feeding of coolant; economical machining owing to replaceable blades	

4. Conclusion

The ALNEX (ANX Series) cutters were developed to respond to market needs. These cutters certainly improve productivity through high-efficiency machining. Additionally, they drastically cut workload such as edge height adjustments resulting from the use of a multi-blade cutter design necessitated by high-efficiency machining. Moreover, substantial improvements in their chip control performance not only eliminate problems, but also extend tool life. Their reduced tool weight enables small machining equipment to operate with high efficiency. The ALNEX (ANX Series) tools contribute to reduced equipment space requirements and a smaller number of machines, as well as machining time and cost reductions.

Technical Term

*1 Polycrystalline sintered diamond (PCD): Particles of diamond, the hardest known material on Earth, sintered to offer high hardness and superb wear resistance.

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