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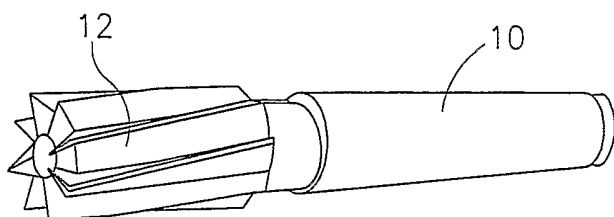
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(54) Title: TORSIONALLY-STIFF END MILL



(57) Abstract: The invention relates to a tools for the milling of materials. The invention provides improved torsional and bending rigidity of tool's body in an end-mill, thereby to extend tool life while making possible machining at increased metal removal rates, and better surface quality, while preventing vibration. The end mill of outer diameter D configured for improved rigidity, comprising a body portion to be gripped by a machine tool and a cutting portion having a plurality of flutes machined to form cutting teeth adjacent to said

flutes, the rear of each tooth comprising a short peripheral relief section starting at the cutting edge, and an arcuate extended-length tooth backing portion adjoining the peripheral relief section and ending in a corner formed between the extended length tooth backing portion and the flute, the corner being spaced from the outer diameter D by a distance C, the value of C being in the range 0 to 0.20D.

TORSIONALLY- STIFF END MILL

Background of the Invention

The present invention relates to tools for the milling of materials.

More particularly, the invention provides improved torsional and bending rigidity of tool's body in an end-mill, thereby to extend tool life while making possible machining at increased metal removal rates, and better surface quality, while preventing vibration.

End-mills are widely used in milling operations due to their versatile range of application and due to the moderate first cost of the tool. End-mills are often of cylindrical shape, and are available up to about 80 mm diameter. Many end mills have flat ends; however other shapes such as conical and rounded ends are also used. An end-mill typically has 2 to 10 teeth, depending on diameter, size and whether configured for rough cutting or finishing. Teeth are usually of spiral shape, but can be straight parallel to the axis. Material of construction is high speed steel, solid carbide, cermets or ceramic, or combinations thereof.

In the following text the words "end mill" refer to a cutter made of steel, or of solid carbide, or of hard ceramic materials or combinations thereof, whether the cutter is plated with a hard coating or not.

Torsional and bending rigidity are highly desirable properties in an end mill, particularly for roughing, finishing and super finishing.

During rough machining much material is removed, and the removal of chips from the cutting area requires adequate space between cutting teeth. Such space can only be provided when the number of teeth is low, typically 2 - 4 teeth depending on cutter diameter, and the core diameter of the tool is small, although still large enough to prevent tool breakage. The smaller core diameter may lead to minor loss of accuracy due to tool bending under pressure, but this is of little moment for roughing operations.

In choosing an appropriate core diameter, there is always a need to balance the requirements of chip clearance and coolant access on the one hand, which call for a small core diameter, and on the other hand the demand for tool rigidity and break resistance which require a large core diameter.

High torsional and bending stiffness of an end mill is an advantage also in finishing and supper finissing operations as a better surface finish is obtained.

During rough machining the milling cutter is subjected to high torsion and bending as the machine tool drives the end mill shank while the teeth of the cutter in contact with the work piece encounter high resistance. An end mill with inadequate torsiona and bending l stiffness will vibrate angularly with high amplitude and not achieve high metal removal rates. Attempts to make deep cuts at high feed rates are liable to result in poor accuracy and surface quolity, noise and early breakage of the cutter.

Prior art end mills are seen in US Patents nos. 4,812,087, 5,188,487, 5,971,671, 6,231,275 B1 and the documents cited as references therein. Further prior-art end mills will be seen in FIGS. 1 - 4 in the present text.

Objects of the Invention

It is therefore one of the objects of the present invention to obviate the disadvantages of prior art end mills and to provide a cutter tooth form which has adequate chip clearance flute channels while providing improved torsional rigidity as well as improved bending resistance.

Summary of the Invention

The present invention achieves the above object by providing an end mill of outer diameter D configured for improved rigidity, comprising a body portion to be gripped by a machine tool and a cutting portion having a plurality of flutes machined to form cutting teeth adjacent to said flutes, the rear of each tooth comprising a short peripheral relief section starting at the cutting edge, and an arcuate extended-length tooth backing portion adjoining said peripheral relief section and ending in a corner formed between said

extended length tooth backing portion and said flute, said corner being spaced from said outer diameter D by a distance C , the value of C being in the range 0 to $0.20D$.

In a preferred embodiment of the present invention there is provided an end mill wherein a short concave blending radius connects said peripheral relief section to said arcuate extended-length tooth backing portion.

In a most preferred embodiment of the present invention there is provided an end mill adapted for the machining of soft metals wherein the value C is about $0.06D$ or less and said corner acts to burnish the surface being machined.

Yet further embodiments of the invention will be described hereinafter.

The torsional stiffness J of a body subjected to torque, such as a shaft being twisted and a milling cutter while removing metal during cutting, is related not only to the cross-sectional area of the shaft, but also to the square of the distance each area is removed from the shaft center. The value J is calculated by summing up the various areas of which a section is composed, and multiplying each such area by the square of the distance r , which represents the distance between the centers of each area to the center of the profile. J is usually referred to as the polar moment of inertia, the values of which can be given in cm^4 .

Thus a shaft or a milling cutter subjected to torque can be stiffened by adding one or more areas to its cross-section to increase its J value.

Because the value r appears in the formula for calculating J as r^2 , a very effective method of increasing J is to increase r by positioning the various area components comprising the cross-sectional area as far away from the center of twist as is possible. A simple illustration of this is found when a solid round shaft is replaced by a hollow cylinder or pipe of the same cross-sectional area and of the same weight, resulting in a much stiffer shaft due to the higher J value of the cylinder.

A glance at the diagrams presented in the present specification will make clear that the added areas which are a central feature of the present invention are quite large relative to

the geometrical form of a prior-art milling cutter, and most importantly the extra areas are disposed in proximity to the outer diameter of the cutter.

While the extra areas on the rear face of the end mill teeth serve primarily to reduce torsional deflection while cutting, the additional benefit offered by the new design is in improved resistance to cantilever-type bending of the cutter when held by the machine at the shank end and pressed against the work-piece at the cutting end. As is well known, improved rigidity of the cutter improves the machined surface finish, improves the ability to machine to close tolerances, and with regard to roughing increases the possible metal removal rate, doing so while generating less vibration and less noise.

It will thus be realized that the novel cutting tool of the present invention serves to increase the J value without reducing the size of the flute. By maintaining flute size the flow of coolant to the cutting edges is not disturbed, and more significantly the discharge of chips from the cutting area through the flutes is unobstructed.

Short description of the drawings

The invention will now be described further with reference to the accompanying drawings, which represent by example preferred embodiments of the invention. Structural details are shown only as far as necessary for a fundamental understanding thereof. The described examples, together with the drawings, will make apparent to those skilled in the art how further forms of the invention may be realized.

In the drawings:

FIG. 1 is a perspective view of a prior-art end mill;

FIG. 2 is an end view of a prior-art end mill having 2 teeth;

FIG. 3 is an end view of a prior-art end mill having 5 teeth;

FIG. 4 is an end view of a prior-art end mill having 6 teeth;

FIG. 5 is a view of a preferred embodiment of the end mill according to the invention, showing the added material in the dotted area;

FIG. 6 is a detail view of the tooth form showing an intermediate blending radius;

FIG. 7 is a perspective view of a ball nose end mill, while

FIG. 8 is an end view thereof;

and

FIG. 9 is an end view of an end mill for milling soft metals and plastics.

Full description of the Invention

There is seen in FIG. 1 a prior art end mill having a shank or body portion 10 and a cutting portion 12. The end mill seen has 8 teeth and an outside diameter large enough (about 50 - 80 mm diameter) to allow chip clearance between teeth.

The prior art cutter seen in FIG. 2 has two teeth 14, each tooth having a backing portion 16 which recedes to the core diameter 18 over about 160° . The C value is about 0.58 .

The prior art end mill seen in FIG. 3 has 5 teeth 20, each having a backing portion 22 which recedes to a position about halfway between the core diameter 24 and the outside diameter D.

FIG. 4 illustrates a prior art 6-tooth cutter 26. The tooth form 28 has a negative rake as it is intended to machine high hardened ~ more 55HRC steels, the tool 28 being made of sintered carbide.

Turning now to FIG. 5, there is depicted a 3-tooth end mill configured for improved rigidity according to the present invention. The end mill comprises a body portion 10, seen in FIG. 7, to be gripped by a machine tool, and a cutting portion seen in the figure which has an outer diameter D.

Three flutes 30 are machined along the cutting portion to form cutting teeth 32 adjacent to said flutes. The rear of each tooth 32 comprises a short peripheral relief section 34 starting at the cutting edge. As described so far, the cutter accords with the prior art.

An arcuate extended-length tooth backing portion 38 adjoins the peripheral relief section 34 and ends in a corner 40 formed between the extended-length tooth backing portion 38 and the adjacent flute 30. The corner 40 is spaced from the outer diameter D by a distance C, the value of C being in the range 0 to 0.20D. For example, in a 16 mm diameter end mill C will be in the range 0 mm to 3.2 mm. The low C values mean that substantially

more material is available to rigidize the tooth. The extra material seen in the dotted area 42 is disposed far from the center of the end mill, and so greatly increases the torsional rigidity J of the tool, while also improving bending rigidity.

By choosing a moderate rake angle ($0 - 8^{\circ}$), the end mill is readily configured for roughing applications, particularly for metals having a machinability rating below 40 on a scale where free-cutting brass has a machinability rating of 100 and 316 stainless steel has a rating of 10.

With reference to the rest of the figures, similar reference numerals have been used to identify similar parts.

FIG. 6 illustrates a detail of an end mill wherein a short concave blending radius 44 chamfer connects the peripheral relief section 46 to the arcuate extended-length tooth backing portion 48. The radius or chamfer 44 is helpful in preventing stress concentration when the cutter is in use.

Seen in FIGS. 7 and 8 is an end mill 50 formed as a ball-nose cutter. The end mill is otherwise similar to that described with reference to FIG. 5.

Referring now to FIG. 9, there is depicted a further end mill according to the invention, being adapted for the machining of soft materials, such as free-cutting steel, non-ferrous metals and plastics. The value of C is about $0.03D$. The solid core 52 has a diameter of about $0.4D$.

The cutter has 2 teeth 54, each having rake angles of $10^{\circ} - 20^{\circ}$. The end mill is constructed of high speed steel, or solid carbide, or cermet, or ceramic.

Because of the low C value, the corner 56, between the flute 58 and the arcuate extended-length tooth backing portion 60, may contact the work piece and burnish the surface being machined.

Due to the extra material added at the back of the tooth, the end mill is break resistant even in the smaller sizes, and will generate less vibration and less noise than prior-art end

mills of the same outside diameter. Thus higher metal removing rates can be achieved than were previously possible.

The scope of the described invention is intended to include all embodiments coming within the meaning of the following claims. The foregoing examples illustrate useful forms of the invention, but are not to be considered as limiting its scope, as those skilled in the art will be aware that additional variants and modifications of the invention can readily be formulated without departing from the meaning of the following claims.

WE CLAIM:

1. An end mill of outer diameter D configured for improved rigidity, comprising a body portion to be gripped by a machine tool and a cutting portion having a plurality of flutes machined to form cutting teeth adjacent to said flutes, the rear of each tooth comprising a short peripheral relief section starting at the cutting edge, and an arcuate extended-length tooth backing portion adjoining said peripheral relief section and ending in a corner formed between said extended length tooth backing portion and said flute, said corner being spaced from said outer diameter D by a distance C , the value of C being in the range 0 to $0.20D$.
2. An end mill as claimed in claim 1, wherein a short concave blending radius or chamfer connects said peripheral relief section to said arcuate extended-length tooth backing portion.
3. The end mill as claimed in claim 1, being a ball-nose cutter.
4. The end mill as claimed in claim 1 adapted for the machining of soft metals wherein the value C is about $0.06D$ or less and said corner acts to burnish the surface being machined.
5. The end mill as claimed in claim 1, being configured for general applications.
6. The end mill as claimed in claim 1, being configured for milling non-ferrous materials and plastics.
7. The end mill as claimed in claim 1, being configured for roughing applications on metals having a machinability rating below 40 on a scale where free-cutting brass has a machinability rating of 100 and 316 stainless steel has a rating of 10.

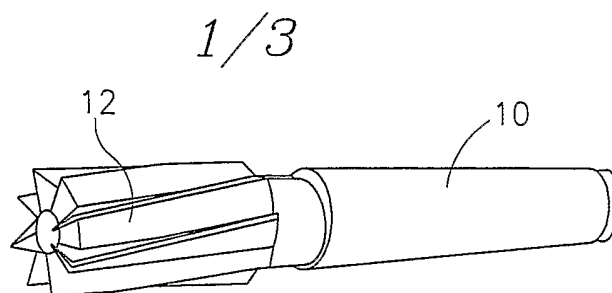


FIG. 1
PRIOR ART

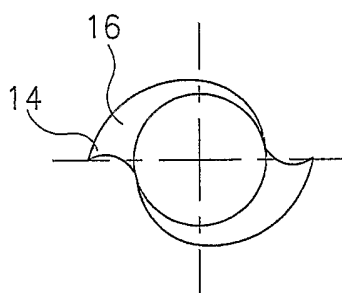


FIG. 2
PRIOR ART

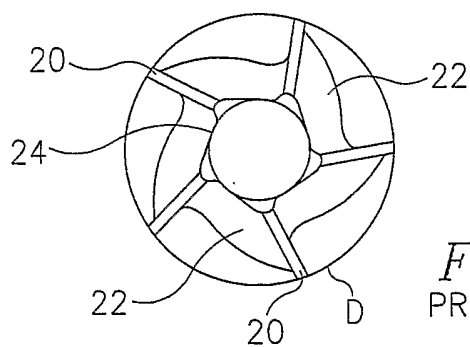


FIG. 3
PRIOR ART

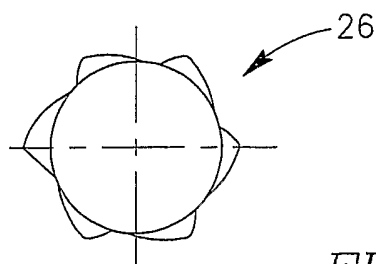


FIG. 4
PRIOR ART

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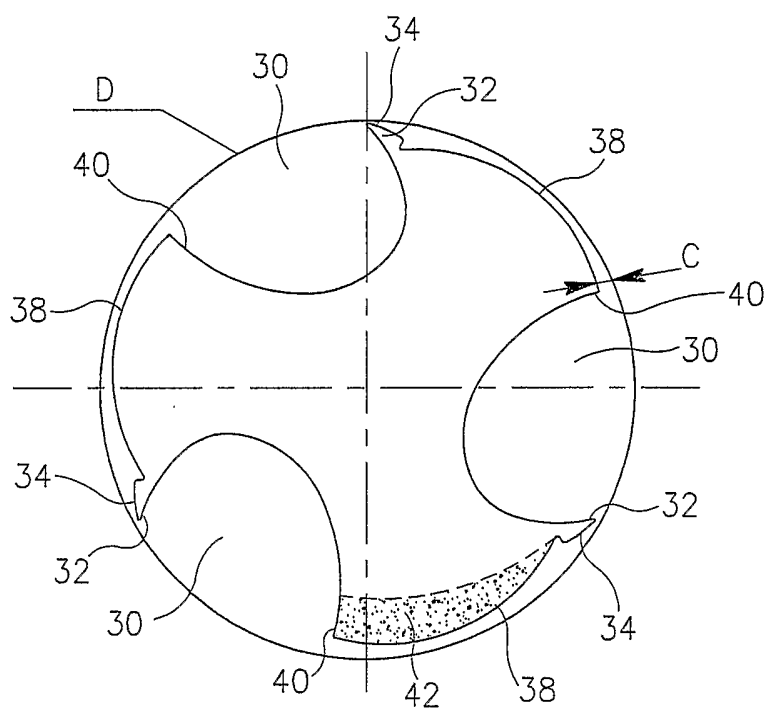


FIG. 5

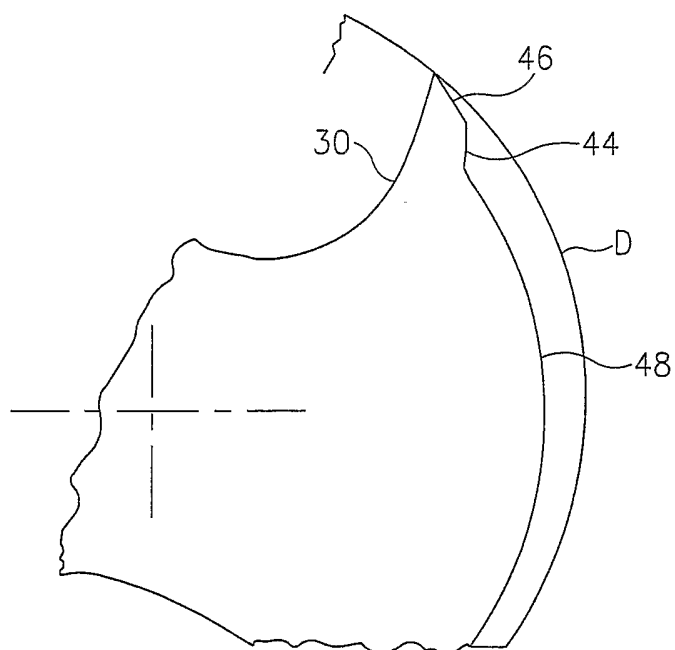


FIG. 6

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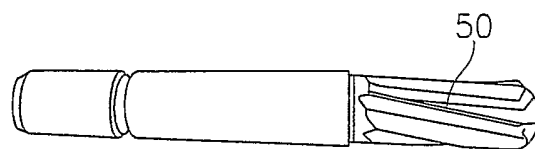


FIG. 7

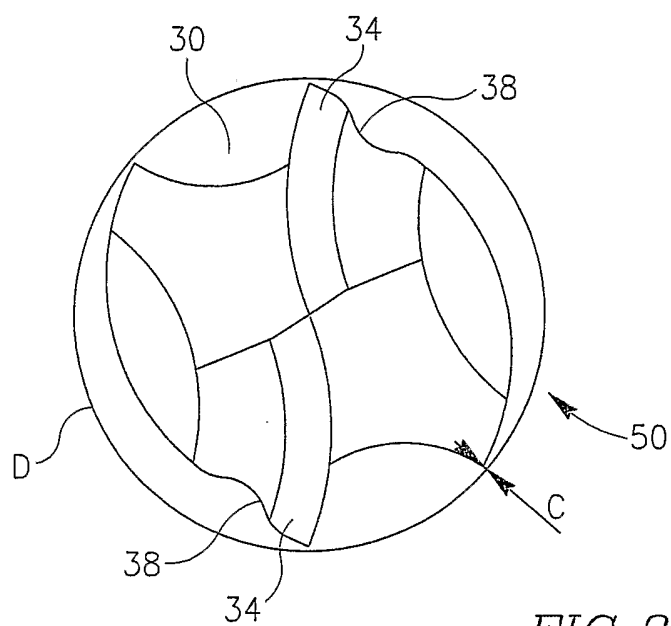


FIG. 8

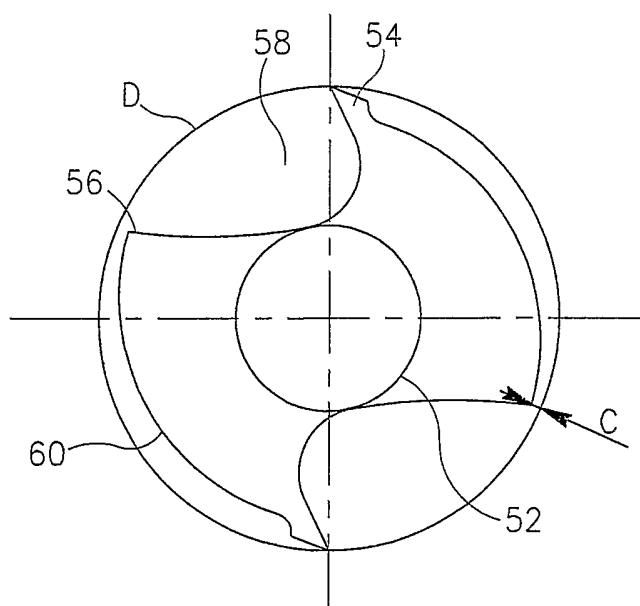


FIG. 9