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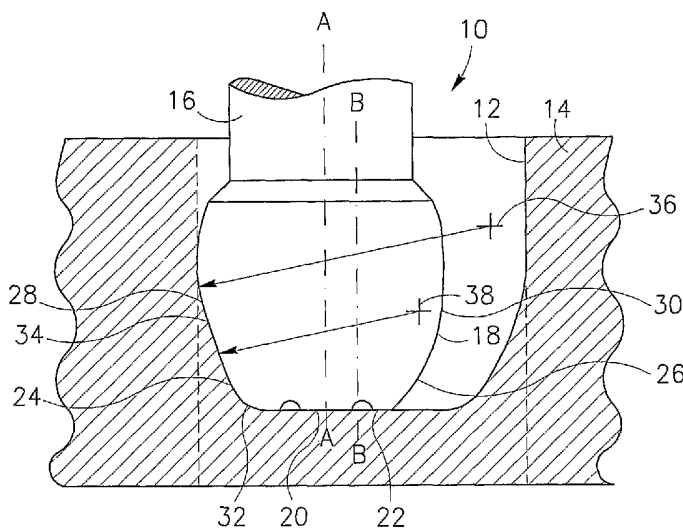
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(54) Title: ORBITAL END MILL



(57) Abstract: The present invention relates to tools for the machining of solid materials, namely an improved end-mill particularly suited for use in an orbital mode in the milling of recesses. The orbital milling tool for cutting openings in a solid material, wherein the openings include normal cylindrical through holes, blind holes, holes including recesses, screw threaded holes, tapered holes and double tapered holes, aid tool having a shank portion adjoining a cutting portion, the axis of the cutting portion being spaced apart from the spindle axis of a machine tool in which the shank is to be held. The cutting portion having a plurality of roughing cutting edges, a plurality of semi-finishing edges axially spaced apart by means of a first transition section from the roughing cutting edges and a plurality of finishing edges axially spaced apart by means of a second transition section from the semi-finishing cutting edges. The maximum diameter of the semi-finishing edges being larger than said roughing cutting edges and smaller than the finishing edges.

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ORBITAL END MILL

Field and background of the invention

The present invention relates to tools for the machining of solid materials.

- 5 More particularly, the invention provides an improved end-mill particularly suited for use in an orbital mode in the milling of recesses.

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
10 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.

15 In the following text the words "end mill" refer to a cutter made of steel or of hard ceramic materials or combinations thereof, whether the cutter is plated with a hard coating or not. Also, the term "milling machine" as used in the present text is to be interpreted as also including other suitable machine tools, such as lathes, borers and heavy duty drilling
20 machines.

An end mill normally held in a milling machine will, when fed into a work piece, will produce a hole or recess of a diameter corresponding to the diameter of the cutting teeth of said end mill. However where desired it is possible to machine a hole of a size larger than the
25 diameter of the end mill by mounting the end mill on a tool holder in a manner where the axis of the milling machine spindle and the axis of the end mill are spaced apart and parallel. This fixed orbital circle is however of limited use. Using a modern CNC milling machine the end mill can be mounted normally and variable orbital movement is available, as needed, for example, for the machining of tapered holes. This orbital arrangement has been found to be
30 particularly useful for the machining of blind holes and for the machining of female screw threads.

As is known, the tool cutting angles for rough machining requiring maximum rates of metal removal are different from the optimum tooth shape for finish machining where small

amounts of metal are removed but a good surface finish is required. Obviously it is possible to change the end mill on completion of rough machining and again exchange the end mill to machine the next component; or to rough machine a batch which is later finish machined. Neither option is desirable, as much time is lost either on tool changing or on work piece
5 reclamping. For this reason double-purpose tools have been developed where an end mill or other tool carries at least one tooth for rough machining and a second tooth for finishing.

The following recent US Patents will provide an assessment of the prior art.

10 In US Patent no. 5,727,910 Leeb discloses a cutting tool including an insert having a plurality of cutting edges of inwardly directed V shaped geometry. The insert has inner and outer flank cutting edges with rounded corners. The cutting edge is divided into by a chisel edge into roughing and finishing cutting portions.

Two known problems with regard to screw-on inserts are that high precision in positioning
15 the insert is required to avoid over-size holes, and the screw holding the insert has a tendency to loosen due to vibration of the tool when in use. Yet a further problem regarding tools using two inserts is that high precision is indispensable in the settings of the two inserts which need to be identical. Due to the size of the insert which must be large enough to allow setting and clamping, small and medium size holes can not be machined.

20 A somewhat similar insert is described by Aström et al. in US Patent no. 6,193,446 B1. On side surfaces a clearance surface formed on a protruding portion which, via a step clearance extends into a secondary helically twisted clearance surface, the chip angle of which increases with increasing cutting depth. The insert includes a chip breaker.

25 Wardell, in US Patent 6,439,811 B1 claims an end mill wherein at least one flute defines a low angle cutting surface while a second flute has a high angle cutting surface. The two flutes intersect to form a compound cutting surface.

30 Kuroda et al. disclose a flat-bottom end mill with rounded corners in US Patent no. 6,846,135 B2. The corner configuration described is claimed to improve resistance to chipping and fracture of the end mill.

A large number of tooth forms for end mills are known, including tooth forms disclosed by the present inventor in previous Israel and US Patents. In order to decide which form is best it would be necessary to run comparative and extensive machining tests on cutters made according to the various disclosures in the literature. Such tests have not been carried out due
5 to the high expense involved. Presently most inventors test run the form of their choice in a workshop, but even where machining test results are published, conditions of machining (material hardness, cutter diameter and material, number of teeth, machine rigidity, machining speed and feed, coolant composition, surface finish quality, whether the end mill is nitride coated or not, and yet further factors) are not standardized and can not be compared. In the
10 absence of comparative test results it is not possible to assess the merits of prior-art disclosures.

The end mill according to the present specification has however been extensively tested and has been found to have improved machining results when used on practical work pieces, in
15 comparison with standard end mills previously used for such application.

Objects of the invention

It is therefore one of the objects of the present invention to provide a new end mill configuration particularly suited for orbital milling.

20 It is a further object of the present invention to improve the surface finish of machined circular-section recesses by the provision of at least one semi-finishing cutting section.

Yet a further aim of the present invention is to provide an end mill capable of orbital machining a 3-5 mm and larger diameter hole.

25 Summary of the invention

The present invention achieves the above objects by providing an orbital milling tool for cutting openings in a solid material, wherein said openings include normal cylindrical through holes, blind holes, holes including recesses, screw threaded holes, tapered holes and double tapered holes, aid tool having a shank portion adjoining a cutting portion, the axis of said
30 cutting portion being spaced apart from the spindle axis of a machine tool in which said shank is to be held, said cutting portion having a plurality of roughing cutting edges, a plurality of semi-finishing edges axially spaced apart by means of a first transition section from said roughing cutting edges and a plurality of finishing edges axially spaced apart by means of a second transition section from said semi-finishing cutting edges, the maximum diameter of

said semi-finishing edges being larger than said roughing cutting edges and smaller than said finishing edges.

5 In a preferred embodiment of the present invention there is provided a tool wherein said transition sections are straight.

In a further preferred embodiment of the present invention there is provided a tool wherein said transition sections are curved.

10 In a most preferred embodiment of the present invention there is provided a tool wherein the length of said second transition section is zero.

It will be realized that the novel shape of the end mill of the present invention serves to make possible the machining of complex hollows using a CNC milling machine. Furthermore, as
15 the machining pressure is divided along an extended line, a good surface finish is achieved together with good rates of metal removal.

Due to the avoidance of inserts in the present invention, openings as small as 3-5 mm can be machined, this is not possible when using screw-on inserts.

20

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
25 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:

30 FIG. 1 is a part-sectional elevation of a first preferred embodiment of the end mill tool according to the invention, seen milling a circular cylindrical recess;

FIG. 2 is a part-sectional elevation of a second preferred embodiment of the end mill tool seen milling a circular-section taper;

FIG. 3 is a part-sectional elevation of a third preferred embodiment of the end mill tool shown milling a circular-section double taper recess;

and

FIG. 4 is a part-sectional elevation of an embodiment of the end mill tool, shown milling a recess and simultaneously cutting a female screw thread therein.

Full description of the invention

There is seen in FIG. 1 an orbital milling tool 10 for machining the sides of a circular-section opening 12 in a solid material 14 such as metal, wood, and plastic or in components made thereof. The opening 12 seen in the figure is a normal cylindrical through hole, being machined by the tool 10. As is evident in the diagram a blind hole could also be produced, if the deeper portion of the hole could have a substantially tapered end.

The tool 10 has a shank portion 16 adjoining a cutting portion 18. The axis AA of the cutting portion 18 is spaced apart from the spindle axis BB of a machine tool, not shown, in which the shank 16 is gripped. For the machining of the parallel sided opening 12 the distance between AA and BB can be set and locked. Machining is done when the machine tool drives the tool in a circular orbit about axis BB while feeding the tool downwards.

The profile of the cutting portion 18 displays two or more rough cutting edges 20, 22, two or more semi-finishing edges 24, 26 spaced apart from each other 180° and apart from the finishing edges 28, 30 by means of a curved first transition section 32.

A second curved transition section 34 joins the finishing edges 28, 30 to the semi-finishing cutting edges 24, 26.

Each section 20 - 30 has an optimum tooth shape for its task.

As is evident from the figure, the maximum diameter of the semi-finishing edges is larger than the roughing cutting edges and smaller than the finishing edges.

The locus 36 of the radius of curvature for the finishing section 28, 30 is seen outside the end mill profile.

However the locus 38 of the radius of curvature for the semi-finishing section 24, 26 is located inside the end mill profile.

In the present embodiment the transition sections 32, 34 are curved.

A chip-breaker (not shown), useful during the machining of ductile materials such as copper, mild steel and aluminum can be optionally provided.

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

Referring now to FIG. 2, there is seen an end mill tool 40 generally similar to the tool 10 seen in FIG. 1. The tool 40 has transition sections 42, 44 which are straight.

The tool 40 is seen machining a tapered hole 46. The minimum possible diameter at the narrow end of the tapered hole 46 being machined corresponds to the maximum diameter of the finishing section 48 of the tool 40.

During the machining operation shown in the figure a CNC Milling machine (not shown) gradually drives the tool holder (not seen) so as to bring the axis AA of the tool 40 nearer the machine spindle axis BB to the tool 10 seen in FIG. 1. The tool 50 is seen being used to cut a recess having both a top taper 52 and a bottom taper 54.

In the present embodiment the length of the second transition section 42 is zero. This is achieved by slight adjustment of the radii locus 36, 38.

Seen in FIG. 4 is a special purpose end mill tool 56 configured for thread milling

The lower portion 60 of the tool 56 is similar to that seen in FIG. 1. A V-shaped tooth 62 projects from the upper part 66 of the cutting portion and cuts a female screw thread 68 at the same time as the recess 58 is being machined by the roughing teeth 72, 74 and the semi-finishing portion 64 of the tool.

As the grooves of the screw thread 68 follow a helical path the head of the CNC milling machine is slanted in relation to the work piece 70. The slant is not seen in the diagram as the direction thereof is in the Z axis.

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 orbital milling tool for cutting openings in a solid material, wherein said openings include normal cylindrical through holes, blind holes, holes including recesses, screw threaded holes, and tapered holes, said tool having a shank portion adjoining a cutting portion, the axis of said cutting portion being spaced apart from the spindle axis of a machine tool in which said shank is to be held, said cutting portion having at least one roughing cutting edges, a plurality of semi-finishing edges axially spaced apart by means of a first transition section from said roughing cutting edges and a plurality of finishing edges axially spaced apart by means of a second transition section from said semi-finishing cutting edges, the maximum diameter of said semi-finishing edges being larger than said roughing cutting edges and smaller than said finishing edges.
2. The tool as claimed in claim 1, wherein said transition sections are straight.
3. The tool as claimed in claim 1, wherein said transition sections are curved.
4. The tool as claimed in claim 1, wherein the length of said second transition section is zero.
5. The tool as claimed in claim 1, including a chip-breaker.
6. The tool as claimed in claim 1, wherein said cutting portion has a single flute.
7. The tool as claimed in claim 1, wherein said cutting portion has a plurality of flutes.
8. An orbital milling tool substantially as described hereinbefore and with reference to the accompanying drawings.

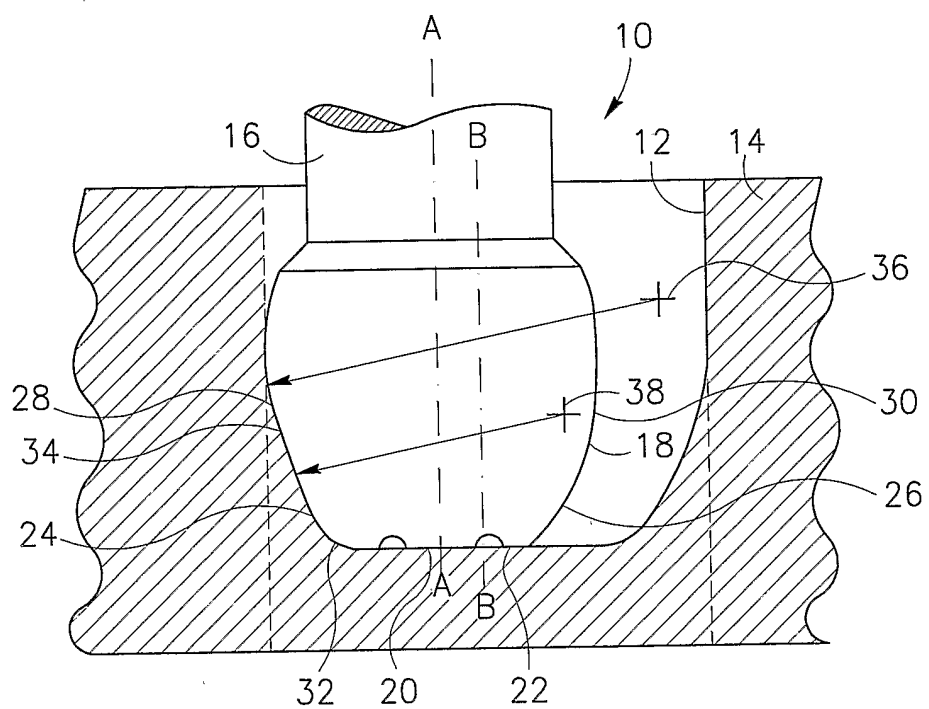
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FIG.1

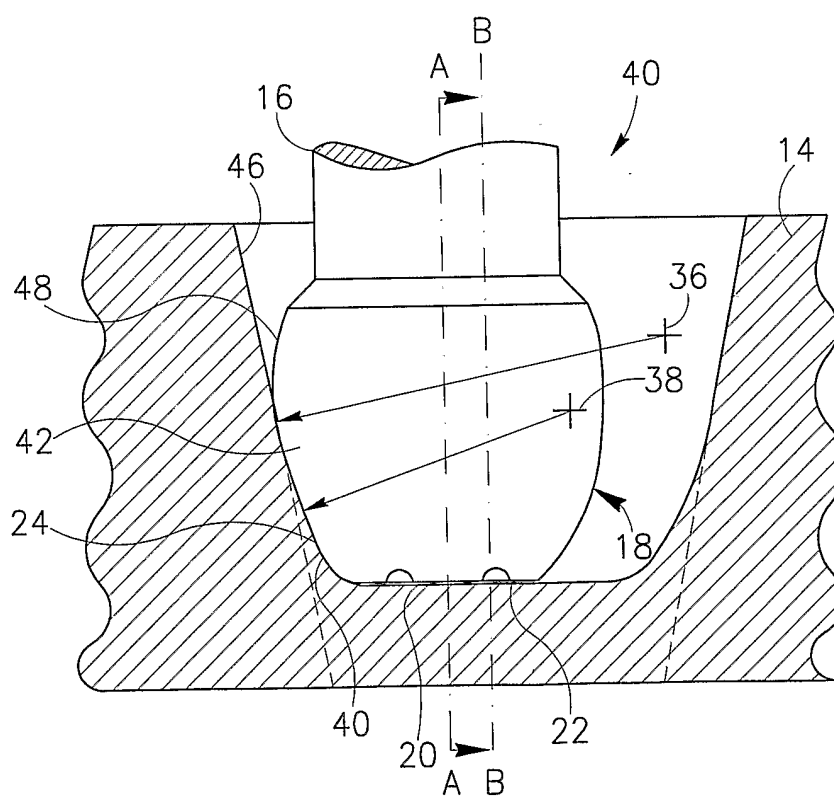


FIG. 2

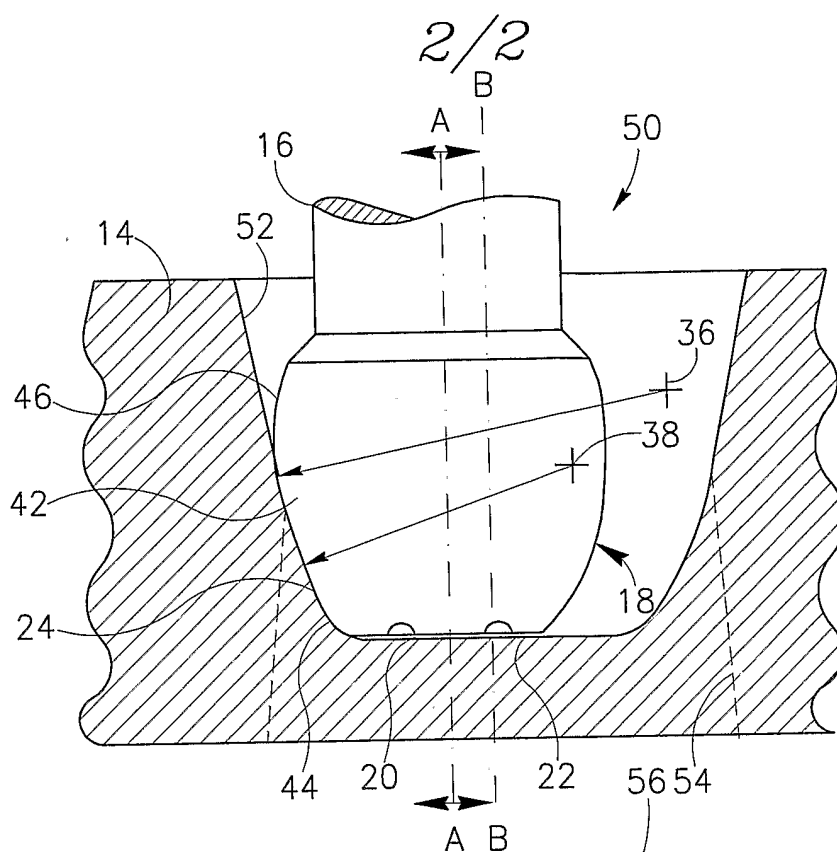


FIG. 3

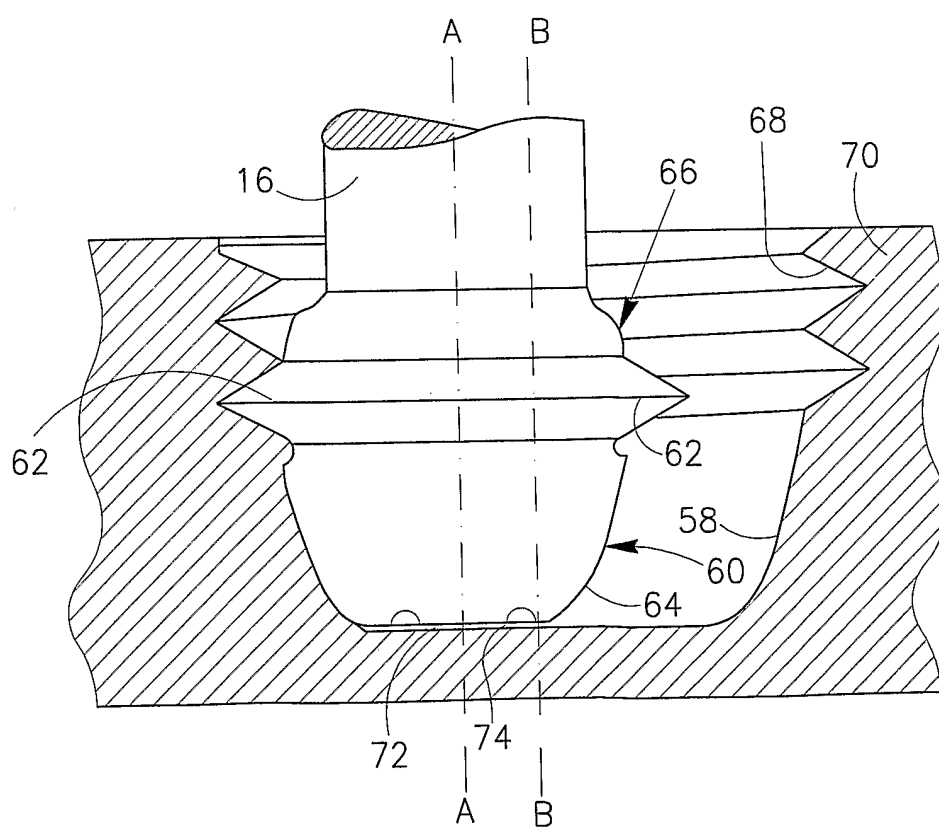


FIG. 4