WORKPIECE MACHINING METHOD, MACHINE TOOL, TOOL PATH-GENERATING DEVICE AND TOOL PATH-GENERATING PROGRAM

(57) A workpiece machining method that machines a workpiece surface (60) by moving a rotating tool (54), which has a cutting blade (54a) for interrupted cutting of the workpiece surface (60), relative to the workpiece (6) comprises: a first process of determining the pattern of arrangement of multiple cavities (610) on the surface of the workpiece formed after cutting by the cutting blade (54a); and a second process of determining the tool path (PA) of the rotating tool (54) so that the multiple cavities (610) are disposed on the surface of the workpiece according to the pattern of arrangement determined in the first process.
The present invention relates to a machining method of a workpiece and a machine tool for machining a workpiece surface by a rotary tool and to a tool path generating device and tool path generating program for generating a tool path for machining a workpiece surface.

BACKGROUND ART

When using an end mill or other rotary tool to cut a workpiece surface, the workpiece surface is cut intermittently by the cutting blade. For this reason, the machined workpiece surface generally has a plurality of remaining convex uncut parts called "cusps". Between the cusps, arc shaped dimples are formed. As a machining method which considers the shape error of the workpiece surface due to such cusps, for example, the machining method which is described in the following Patent Literature 1 is known.

In the machining method which is described in Patent Literature 1, while a rotary tool is made to move along the machining points while machining the workpiece surface, the rotary tool is made to rotate by one blade’s worth of rotational angle between the machining points. On the other hand, a machining method which divides a machining surface by polygonal shaped patches and machines the insides of the patches along spiral shaped tool paths to form regular surface patterns at the machined surface is also known (for example, see Patent Literature 2).

However, neither of the methods which are described in the above Patent Literatures 1 and 2 considers how the arc shaped dimples which are formed at the machined workpiece surface are arranged at the workpiece surfaces as a whole. Therefore, for example, when machining a first machining area of the workpiece surface, then machining a second machining area which adjoins this first machining area, the dimples are formed regardless of the dimples of the first machining area. As a result, incompletely shaped dimples are liable to be formed at the boundary part of the first machining area and second machining area and these incompletely shaped dimples are liable to cause streak patterns and other undesired machining marks to remain at the workpiece surface.

SUMMARY OF INVENTION

The present invention provides a machining method of a workpiece having a cutting blade for intermittently cutting a workpiece surface move relative to the workpiece to machine the workpiece surface, which includes a first step of determining a pattern of arrangement of a plurality of dimples at the workpiece surface formed after cutting by the cutting blade and a second step of determining a tool path of the rotary tool so that the plurality of dimples are arranged at the workpiece surface in accordance with the pattern of arrangement determined at the first step.

Further, the present invention provides a tool path generating device generating a tool path for machining a workpiece surface with a rotary tool having a cutting blade for intermittently cutting the workpiece surface, which includes a dimple setting part setting a pattern of arrangement of a plurality of dimples at the workpiece surface formed after cutting by the cutting blade, and a path generating part generating a tool path of the rotary tool so that the plurality of dimples are arranged at the workpiece surface in accordance with the pattern of arrangement set at the dimple setting part.

Further, the present invention provides a machine tool machining a workpiece surface with a rotary tool having a cutting blade for intermittently cutting the workpiece surface, which includes the above tool path generating device and a machine body making the rotary tool rotate while moving the rotary tool relative to the workpiece in accordance with a tool path generated by the tool path generating device so as to machine the workpiece surface.

Still further, the present invention provides a tool path generating program making a computer generate a tool path for machining a workpiece surface with a rotary tool having a cutting blade for intermittently cutting the workpiece surface, which makes the computer run a first routine of setting a pattern of arrangement of a plurality of dimples at the workpiece surface formed after cutting by the cutting blade and a second routine of generating a tool path of the rotary tool so that the plurality of dimples are arranged at the workpiece surface in accordance with the pattern of arrangement set at the first routine.

CITATIONS LIST

PATENT LITERATURE


BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a view which shows the general configuration of a machine tool according to an embodiment of the present invention.
FIG. 2 is a front view which shows one example of a machine body of FIG. 1.
FIG. 3 is an enlarged view of a tool which is used at the machine body of FIG. 2 and which shows a state of machining of the workpiece surface.
FIG. 4A is a plan view which shows one example of
DESCRIPTION OF EMBODIMENTS

Below, referring to FIG. 1 to FIG. 14, an embodiment of a machine tool according to the present invention will be explained. FIG. 1 is a view which shows a general configuration of a machine tool 100 of the present invention. This machine tool 100 has a control device 1 which prepares a machining program which includes a path for machining a workpiece surface and machines the workpiece surface in accordance with the machining program prepared by the control device 1.

The control device 1 is a computer which is comprised of a processing system which has a CPU, ROM, RAM, and other peripheral circuits, etc. Functionally, as shown in FIG. 1, it has a mesh preparation part 11, machining sequence setting part 12, data converting part 13, and display control part 14. The control device 1 has a CAD unit (computer aided design unit) 3 and input device 4 connected to it, receives as input from the CAD unit 3 3D shape data which corresponds to the machined shape of the workpiece, and receives as input from the input device 4 various data which is required for preparing the machining program. The display control part 14 controls a display device 2.

The machining program which is prepared by the control device 1 is output to the NC unit (numerical control unit) 5. The NC unit 5 uses this machining program as the basis to control the machine body 50 and uses the machine body 50 to machine the workpiece surface. FIG. 2 is a front view which shows one example of the machine body 50. Here, a vertical machining center is shown.

As shown in FIG. 2, a column 52 is provided on a bed 51, and the spindle head 53 is supported movably in the up-down direction (Z-axial direction) through a linear feed mechanism. A tool 54 is attached to the spindle head 53 facing downward through a spindle. The tool 54 is a rotary tool which has a cutting blade which intermittently cuts a surface 60 of a workpiece 6 and is, for example, comprised of a ball end mill. The tool 54 is driven by a spindle motor 58 in the spindle head 53 to rotate about an axial line L0 parallel to the Z-axis.

On the bed 51, a saddle 55 is supported movably in the horizontal direction (Y-axial direction) through a linear feed mechanism. The saddle 55, a table 56 are supported movably in the up-down direction (Z-axial direction) through a linear feed mechanism. A tool 54 is attached to the spindle head 53 facing downward through a spindle. The tool 54 is a rotary tool which has a cutting blade which intermittently cuts a surface 60 of a workpiece 6 and is, for example, comprised of a ball end mill. The tool 54 is driven by a spindle motor 58 in the spindle head 53 to rotate about an axial line L0 parallel to the Z-axis.

The machine body 50 may further have A-axial, B-axial, and C-axial rotation drive shafts. The workpiece 6 is, for example, a shaping die for which precision surface finishing is demanded.

FIG. 3 is an enlarged view of a tool 54 which shows the machining state of the workpiece surface 60. In FIG. 3, the B-axis is tilted and the vertical line L1 of the tool 54 is shown tilted relative to the workpiece surface 60. The angle which is formed by the axial line L0 of the tool 54 and the vertical line L1 of the workpiece surface 60 is made a predetermined angle θ which is larger than 0° (for example, 45°). As shown in FIG. 3, the tool 54 which is used in the present embodiment is a ball end mill which has a predetermined number of spiral shaped cutting blades 54a at its circumferential surface and a front end part which exhibits an arc shape. Below, for simplification of the explanation, the tool 54 is assumed to be a single blade ball end mill which has a single cutting blade 54a. The shape of the front end of the tool, which is based on the explanation, the tool 54 is assumed to be a single blade ball end mill which has a single cutting blade 54a. The shape of the front end of the tool, which is based on the center 54b of the ball of the front end part of the tool, is known in advance. The position of the tool 54 can be specified by the coordinates of the center 54b.

When making the tool 54 rotate and making it move relative to the workpiece 6 to machine the workpiece surface 60, the workpiece surface 60 is intermit-
The amount of feed \( \Delta P \) between the machining points \( P_0, P_0 \) along the arrows PA are equal to each other. Each distance \( \Delta P \) corresponds to the amount of one blade of feed (also called simply "amount of feed"). A distance \( \Delta P \) between the machining points \( P_0, P_0 \) in the Y-axial direction corresponds to an amount of pick feed. In the present embodiment, a single blade ball end mill is used, so the tool 54 rotates one revolution during moving from one machining point \( P_0 \) to the next machining point \( P_0 \). By making the tool 54 rotate while making it move relatively along the tool path PA, the workpiece surface 60 is cut by the cutting blade 54a whereby the workpiece surface 60 is formed with spherical surface shaped dimples 61 corresponding to the tool shape.

The amount of feed \( \Delta P \) of FIG. 4A is smaller than the diameter \( D \) of the dimples 61. The dimples 61 partially overlap. As a result, as shown in FIG. 4B, between one adjoining dimple 61 and another dimple 61, a convex shape is formed, i.e., a cusp 62, is formed. In FIG. 4A, if expressing one dimple 61 and its surrounding dimples 61 by respectively \( 61a \) and \( 61b \), six dimples \( 61b \) are formed evenly around one dimple \( 61a \) so as to partially overlap with the dimple \( 61a \). At the boundary parts of the dimple \( 61a \) and the dimples \( 61b \), straight intersection lines 63 are formed. Therefore, the shapes of the machined dimples become a hexagonal shape (solid lines) in the plan view surrounded by six intersection lines 63.

FIG. 5 is a view which shows the positional relationship between the dimples \( 61 \) which are formed at the workpiece surface 60 and the machining points \( P_0 \). In FIG. 5, the center point of a spherical shaped dimple 61 (i.e., median point of adjoining cusps 62, 62) is designated as \( P_1 \), while the design-stage workpiece surface ignoring the formation of the cusps 62 is designated as 60a. As shown in FIG. 5, the center points \( P_1 \) of the dimples 61 are positioned on the workpiece surface 60a, while the machining points \( P_0 \) are set at positions separated from the center points \( P_1 \) by predetermined distances \( \Delta L_1 \). Therefore, the tool path PA which connects the machining points \( P_0 \) is formed separated from the workpiece surface 60a by the predetermined distance \( \Delta L_1 \). Here, \( \Delta L_1 \) is the distance from the center \( 54b \) of the tool 54 shown in FIG. 3 to the outer circumferential surface of the cutting blade 54a of the front end part of the tool, i.e., corresponds to the radius of the ball at the front end part of the tool. The maximum distance between the design-stage workpiece surface 60a and the actual workpiece surface 60 corresponds to the cusp height \( \Delta L_2 \).

As shown in FIG. 4A, if setting the machining points \( P_0 \) uniformly above the workpiece surface 60 (strictly speaking, the design-stage workpiece surface 60a) to generate the tool path PA and making the tool 54 rotate by one blade's worth of angle between the machining points, it is possible to uniformly arrange a plurality of dimples 61 at the workpiece surface 60. However, when a machining area include a plurality of mutually adjoining machining areas (first machining area and second machining area), the tool path is formed independently at each machining area, so incompletely shaped dimples are liable to be formed at the boundary part of the first machining area and the second machining area. This problem will be explained with reference to FIG. 6.

FIG. 6 is a plan view of a workpiece surface 61 which includes a first machining area \( AR_1 \) and a second machining area \( AR_2 \). The "machining area" is an area which is machined along a predetermined tool path, i.e., an area with a constant machining pattern. In other words, the tool path is set for each machining area. The tool paths at the different machining areas are discontinuous. As shown in FIG. 6, in the first machining area \( AR_1 \) and second machining area \( AR_2 \), like in FIG. 4A, the pluralities of machining points \( P_0 \) are evenly set.

Assuming that the first machining area \( AR_1 \) is machined along the tool path \( PA_1 \), then the second machining area is machined along the tool path \( PA_2 \) which is independent from the tool path \( PA_1 \). In this case, the positions of the dimples \( 61 \) in the first machining area \( AR_1 \) have no relation with the positions of the dimples \( 61 \) in the second machining area \( AR_2 \). For this reason, at the boundary part \( AR_3 \) of the first machining area \( AR_1 \) and the second machining area \( AR_2 \), incompletely shaped dimples \( 61c \) are formed. Due to these incompletely shaped dimples \( 61c \), streak patterns and other machining marks are liable to be left at the workpiece surface. Such machining marks are not particularly preferable for a workpiece 6 where machining quality of the surface (for example, a die) is demanded. Therefore, in the present embodiment, the control device 1 is configured in the following way so that the workpiece surface 60 is not formed with streak patterns or other machining marks.

The mesh preparation part 11 of FIG. 1 receives as input signals from the input device 4. The input device 4 is configured by a keyboard, touch panel, etc. The
shape, dimensions, etc. of the dimples which are formed on the workpiece surface 60 can be input.

[0026] As the shape of the dimples, in addition to the hexagonal shape of FIG. 6, a triangular shape, rectangular shape, pentagonal shape, or various other shapes can be input. FIG. 7 shows an example where the shape of the dimples is a rectangular one (in particular, a square one). FIG. 7 shows together an example of the machining points P0 corresponding to the center positions of the dimples 61 and tool path PA.

[0027] The dimension of the dimples 61, for example, corresponds to the distance ΔP between center points (machining points P0) of the dimples 61 of FIG. 4A. This value can also be input by the user. The type of the tool 54, number of cutting blades 54a, dimensions of the front end part of the tool 54, feed rate of the tool 54, and other information are also input from the input device 4.

[0028] The mesh preparation part 11 uses the signals from the CAD unit 3 and input device 4 as the basis to prepare a mesh along the shape of the workpiece surface. That is, the mesh preparation part 11 obtains shape data of the design-stage workpiece surface 60a from the CAD unit 3 and obtains the shape and dimensions of the dimples 61 from the input device 4. Further, based on these input data, the mesh preparation part 11 automatically divides the workpiece surface 60a to prepare a mesh. Below, the dimples which are prepared by the mesh preparation part 11, i.e., the virtual dimples which are formed on the design-stage workpiece surface 60a, will be represented by 610 and differentiated from the actual-stage workpiece surface, then sets machining points P0 at positions separated from the center points P1 of the virtual dimples 610 by a predetermined distance ΔL1 (FIG. 5).

[0031] The mesh preparation part 11 divides the design-stage workpiece surface 60a into a mesh and uniformly arranges virtual dimples 610 over the entire workpiece surface, then sets machining points P0 at positions separated from the center points P1 of the virtual dimples 610 by a predetermined distance ΔL1 (FIG. 5).

[0032] The machining sequence setting part 12 successively connects the machining points P0 set by the mesh preparation part 11 to set the machining sequence. The machining points P0 are connected by, for example, displaying an image of the virtual dimples 610 prepared by the mesh preparation part 11 (dimple image) on a display device 2 and having the user use the input device 4 (for example, mouse) to successively select virtual dimples 610 on the dimple screen.

[0033] FIG. 10 is a view which shows one example of the dimple image 21 displayed on the display device 2. The image signal for displaying this dimple image 21 is generated at the display control part 14 based on the signal from the mesh preparation part 11. The display control part 14 controls the display device 2 in accordance with the generated image signal. In the example of FIG. 10, to express the workpiece surface 60a three-dimensionally, the dimple image 21 is displayed in gradations to give shading to the image 21. In FIG. 10, the virtual dimples 610b are displayed as hexagonal shapes. However, the shape of the virtual dimples 610 may change in accordance with the shape of the machined surface of the workpiece 6, the shape of the mesh MS, etc., and is not limited to a hexagonal shape.

[0034] If the dimple image 21 such as shown in FIG. 10 is displayed on the display device 2, the user successively selects part of the virtual dimples 610 (for example, 611 to 615) on the image 21 through the input device 4. Due to this, as shown by the arrows of FIG. 10, a machining sequence PA0 which successively connects the machining points 0P0 corresponding to the virtual dimples 611 to 615 is set. The machining sequence setting part 12 sets the data of the machining points P0 sequenced in this way (coordinate data) as the machining sequence data.

[0035] Rather than the user inputting the machining sequence manually, it is also possible to follow a predetermined rule to automatically set it by the machining sequence setting part 12. For example, as shown by the tool paths PA1 and PA2 of FIG. 9, by repeating successively connecting machining points P0 included in the machining areas AR1 and AR2 along one direction from one end part to the other end part, then shifting by the...
amount of pick feed and successively connecting machining points in the opposite direction, it is also possible to automatically set the machining sequence.

When the set of the machining sequence finishes, the data converting part 13 converts the machining sequence data to NC data which can be read into the NC unit (numerical control unit) 5 and prepares a machining program. The machining program contains coordinate data of the machining points P0 which are sequenced in accordance with the machining sequence PA0 and amounts of rotation (phase of rotation) of the tool 54 between the machining points P0, P0. This machining program is used to define the tool path PA.

The above processing can be realized by making the CPU of the control device 1 run a tool path generating program which is stored in advance in the control device 1. FIG. 11 is a flow chart which shows one example of the processing which is performed at the control device 1 (tool path generating processing). The processing shown in this flow chart is, for example, started by the user operating the input device 4 to input a machining program preparation command. Before input of the machining program preparation command, the mesh preparation conditions which define the shape, dimensions, etc. of the dimples 61 and the shape, dimensions, and other tool data of the tool 54 are input from the input device 4 and stored in the memory.

At step S1, the CAD data is read from the CAD unit 3, and the mesh preparation conditions and other various data input in advance is read. At step S2, a mesh MS is prepared along the workpiece surface 60a which is defined by the CAD data in accordance with the mesh preparation conditions, as shown in FIG. 8.

At step S3, the display control part 14 generates an image signal for displaying the vertices of the mesh MS as centers of the virtual dimples 610, and displays the dimple image 21 on the display device 2, as shown in FIG. 10. At step S4, it is judged whether to confirm the dimple image 21. This processing judges whether to redo the mesh preparation. For example, the user views the display of the dimple image 21 and judges if the dimples 61 which are to be formed on the workpiece surface 60 are the ones intended. Further, if judging that they are the ones intended, the input device 4 is operated to command confirmation of the dimple image 21. Due to this, a positive decision is made at step S5 and the routine proceeds to step S5.

On the other hand, if the user judges that the dimple image 21 has been intended, the input device 4 is operated to command cancellation of the dimple image 21. Due to this, a negative decision is made at step S4 and the tool path generating routine of FIG. 11 is ended. In this case, the user changes the mesh preparation conditions, etc., then the above-mentioned processing is redone.

At step S5, it is judged if the input device 4 (for example, a mouse) has been operated to select a virtual dimple 610 inside the dimple image 21. If a positive decision is made at step S5, the routine proceeds to step S6, while if a negative decision is made, the routine proceeds to step S7. At step S6, the coordinates of the machining points P0 which correspond to the selected virtual dimples 610 are calculated and stored in the memory. At this time, for example, the machining points P0 are stored in the selected sequence so that the machining points P0 are sequenced.

Next, at step S7, it is judged if all of the virtual dimples 610 on the dimple image 21 have finished being selected. This judgment is performed, for example, by judging whether a selection end command has been input by the input device 4. If changing the mode of display of the selected virtual dimples 610 (for example, color), a user can easily judge whether virtual dimples 610 have been selected or not selected. If a negative decision is made at step S7, the routine returns to step S5 where similar processing is repeated. Due to this, the machining sequence data which includes the coordinate data of the machining points P0 and the sequence of the machining points P0, i.e., the machining sequence data which shows the machining sequence PA0 which is shown by the arrows of FIG. 10, is set.

If a positive decision is made at step S7, the routine proceeds to step S8. At step S8, data of the amount of target rotation of the tool 54 between the machining points is added to the machining sequence data, and the machining sequence data is converted to NC data which can be read into the NC unit 5. That is, the machining sequence data is used as the basis to prepare a machining program which includes the tool path PA. Due to this, the processing at the control device 1 is ended.

The NC unit 5 includes a reading part which reads a machining program (NC data), an acceleration control part which controls acceleration and deceleration of motors 58 and 59 of the machine tool 50, and an interpolation processing part which calculates the target amounts of movement in the X-axial direction, Y-axial direction, and Z-axial direction and target amount of rotation of the spindle. Further, it controls the machine tool 50 in accordance with the machining program from the control device 1. In this case, it controls the motors 58 and 59 so that the tool 54 moves relative to the workpiece 6 along the tool path PA included in the machining program while the cutting blade 54a rotates by one blade’s worth of angle between the machining points P0. Due to this, for example, the tool 54 moves while rotating along the tool path for each machining area P01 and P02 of FIG. 9.

As a result, as shown in FIG. 9, the workpiece surface 60 is formed with dimples 61 of the same pattern of arrangement as predetermined virtual dimples 610. Therefore, regardless of whether the machining area is the same, the workpiece surface 60 can be uniformly formed with dimples 61. That is, it is possible to prevent the formation of streak patterns or other machining marks without the formation of incompletely shaped dimples at
the boundary part AR3 of the first machining area AR1 and the second machining area AR2.

[0046] Summarizing the machining method of a work-piece surface according to the above present embodiment, the result becomes as follows: First, through the input device 4, the user sets the shape and dimensions of the dimples 61 to be formed at the workpiece surface 60. After that, if the user inputs a machining program preparation command through the input device 4, the above processing is started at the control device 1 and the mesh MS is automatically prepared in accordance with the mesh preparation conditions (step S2). Further, the dimple image 21 is displayed so that the vertices of the meshes MS become the centers of the virtual dimples 610 (step S3).

[0047] The user views this dimple image 21 and judges whether the dimples 61 which are formed at the work-piece surface 60 are the intended ones and, in accordance with need, redoes the mesh preparation. When not redoing the mesh preparation, it instructs confirmation of the dimple image 21, and operates the input device 4 to successively select virtual dimples 610 on the image. Due to this, the machining sequence data which shows the machining sequence PA0 which successively connects the machining points P0 is set (step S6). If finishing selecting all of the virtual dimples 610, the user inputs a selection end command through the input device 4. Due to this, the machining sequence data is converted to NC data which can be read into the NC unit 5, and a machining program is prepared (step S8). This machining program includes sequence and position data of the machining points P0 and data of the target amount of rotation of the tool 54 between the machining points P0, P0.

[0048] The NC unit 5 controls the motors 58 and 59 of the machine body 50 in accordance with the machining program from the control device 1 to make the center 54b of the tool 54 move along the machining points P0 and to make the tool 54 rotate by the target amount of rotation between the machining points. Due to this, the workpiece surface 60 is machined and the machined workpiece surface 60 is formed with dimples 61 of the same pattern of arrangement as the virtual dimples 610 of the dimple image 21. In this case, the workpiece surface 60 is machined for each machining area, while the workpiece surface 60 is formed and the workpiece surface 60 is machined in accordance with that pattern of arrangement. That is, the pattern of arrangement of virtual dimples 610 is determined in advance and the workpiece surface 60 is machined in accordance with a machining program so that dimples 61 are formed by the same pattern as that pattern of arrangement. Due to this, the workpiece surface 60 can be formed with the desired dimples 61.

(1) The pattern of arrangement of a plurality of dimples 61 on the workpiece surface which is formed after cutting by the cutting blade 54a of the tool 54 in advance (virtual dimples 610) is determined and a tool path PA is set so that a plurality of dimples 610 are arranged on the workpiece surface 60 in accordance with that pattern of arrangement. That is, by processing in the machining data preparation part 1, the design-stage workpiece surface 60a is divided into a mesh to set virtual dimples 610, machining points P0 corresponding to the virtual dimples 610 are calculated, and these machining points P0 are successively connected to set a tool path PA. Due to this, it is possible to uniformly form dimples 61 at the workpiece surface 60 without incompletely shaped dimples being arranged at the boundary part AR3 of different machining areas AR1 and AR2 (FIG. 9).

(2) The design-stage workpiece surface 60a is divided into a mesh in accordance with the mesh preparation conditions input by the input device 4 so as to determine the shape, size, and arrangement of the virtual dimples 610. That is, the pattern of arrangement of virtual dimples 610 is determined in advance and the workpiece surface 60 is machined in accordance with a machining program so that dimples 61 are formed by the same pattern as that pattern of arrangement. Due to this, the workpiece surface 60 can be formed with the desired dimples 61.

(3) Not only the tool path PA obtained by successively connecting machining points P0, but also the amount of rotation of the tool 54 between machining points is set. The tool path and the amount of rotation of the tool are included in the machining program. Due to this, it is possible to form dimples 61 which correspond to the machining points P0 at all times without regard as to the feed speed of the tool 54, the surface shape of the workpiece 6, etc.

(4) The motors 58 and 59 are controlled so that the tool 54 rotates by one blade's worth of angle between the machining points in accordance with a predetermined machining program. Therefore, it is possible to obtain the desired dimples 61 even when the distance between the machining points differ.

(5) The display control part 14 generates an image signal which makes the vertices of the mesh MS prepared by the mesh preparation part 11 the centers of the virtual dimples 610, and displays an image as a dimple image 21 in advance on the display device 2 before machining the workpiece. Due to this, a user can obtain a grasp in advance of the pattern of arrangement of dimples 61 which are to be formed on the workpiece surface 60 and can prevent mistaken conditions to be used to machine the workpiece 6.

[0050] The pattern of arrangement of virtual dimples 610 which are formed on the workpiece surface 60a and tool path PA are not limited to the ones explained above. FIGS. 12 and 13 are views which show other examples of the pattern of arrangement of virtual dimples 610 and tool path PA. As shown in FIG. 12, it is also possible to set a virtual dimple 610a as a reference and set the tool path PA in a spiral shape centered about this virtual dim-
the second machining area AR2 may be set to different
in the first machining area AR1 and the tool path PA2 in
ple 611. Further, as shown in FIG. 13, the tool path PA1
in the first machining area AR1 and the second machining area AR2 may be set to different
directions.

The present invention can be applied to various
shapes of workpieces and can also be applied to settings
of various machining areas AR. For example, as shown
in FIG. 14, it can also be applied to the case where the
workpiece surface 60 is a curved surface in shape and
a first machining area AR1 and a second machining area
AR2 are set bordered on the vertex of the curved surface.
In this case as well, it is possible to form the workpiece
surface as a whole smooth without leaving machining
marks at the boundary part AR3 of the first machining
area AR1 and the second machining area AR2. The
present invention can be applied to part of the machined
surface of the workpiece rather than the entire region.
For example, it is also possible to determine the patterns
of arrangement of the virtual dimples 610 in advance at
the locations where quality finish of the surface is de-
manded and near the boundary parts of the plurality of
machining areas and generate the tool path PA in ac-
cordance with that pattern of arrangement.

In the embodiment, the shapes and di-

mensions of the dimples 61 are designated in advance
by the user. The mesh preparation part 11 is used to
prepare the mesh MS and automatically set the virtual
dimples 610 to meet the designated conditions. The vir-
tual dimples 610 may also be set by manual input by the
user. Rather than have the shape and dimensions of
the virtual dimples 610 determined by the user, it is also pos-
sible to automatically determine them by the control de-
vice 1 in accordance with the shape, etc., of the work-

piece. That is, if determining the pattern of arrangement
dimples 610 of the workpiece surface 60a in advance,
the first step may be any step. The dimple setting part
(mesh preparation part 11) is not limited in configuration
to the one explained above.

As a second step, the tool path PA is determined
through the dimple image 21 of the display device 2, but
if determining the pattern of arrangement of the virtual
dimples 610, then determining the tool path PA along
the pattern of arrangement, the second step may be any step.
It is also possible to automatically set efficient tool paths
PA corresponding to the shapes of the workpieces, etc.,
by the control device 1. The path generating parts (ma-
chinining machining sequence setting part 12 and data
converting part 13) are not limited in configurations to the
ones which are explained above. That is, the constitu-
tion of the control device 1 as a tool path generating device
constituted is not limited in configuration to the one ex-
plained above.

In the above embodiment, the rotary tool 54 is
made to rotate by one blade’s worth of angle between
the machining points, but this may also be realized by
making the rotational speed of the tool 54 constant and
controlling the feed speed by variable control or by mak-
ing the feed speed of the tool 54 constant and controlling
the rotational speed by variable control. This may also
be realized by controlling both the feed speed and rota-
tional speed of the tool 54 by variable control. That is, as
the third step, when controlling the motors 58 and 59 of
a machine tool, it is sufficient to control at least one of
the motors 58 and 59 by variable control.

In the above embodiment (FIG. 9), the pattern
of arrangement of virtual dimples 610 is determined in a
machining area including the first machining area AR1
which is machined by the first machining pattern and the
second machining area AR2 which is machined by the
second machining pattern. However, the present inven-
tion can be similarly applied even in the case of including
three or more different machining areas. Further, even
in a single machining area AR, when the phases of ad-
joining dimples at a tool path before pick and feed of a
tool 54 and a tool path after pick and feed are not uniform
and is irregular deviation in the tool advancing direction,
streak patterns are liable to be generated at the machined
workpiece surface. In this case as well, the present in-
vention can be similarly applied.

So long as making a first routine which sets a
pattern of arrangement of virtual dimples 610 of the work-

piece surface 60a and a second routine which generates
a tool path PA so that a plurality of dimples 61 are ar-

ranged at the workpiece surface 60 in accordance with
this set pattern of arrangement be run by a computer
constituted by the control device 1, the tool path gener-
ating program is not limited in configuration to the one
explained above. Therefore, the processing in the control
device 1 is also not limited to the one which is shown in
FIG. 11. The tool path generating program can be stored
in the control device 1 through various storage media or
communication lines, etc.

In the above embodiment, as the rotary tool 54,
a ball end mill is used. However, so long as a tool which
has a cutting blade which intermittently cuts the work-

piece surface, the present invention can be applied even
when using a radius end mill or using another rotary tool.

In the above embodiment, a three-axis machin-
ing use vertical machining center is used to form the ma-
chine body 50. However, so long as able to make a tool
54 move relative to a workpiece 6 in accordance with a
tool path PA which is generated by a control device 1
and to machine a workpiece surface 60, it is possible to
use another machine body. For example, the tool path
generating device according to the present invention can
be applied to various machine bodies such as a horizontal
machining center, five-axis machining use machining
center or machine body other than a machining center.

According to the present invention, a pattern
of arrangement of a plurality of dimples at a workpiece
surface is determined in advance and the tool path of the
rotary tool is determined so that dimples are arranged in
accordance with the determined pattern of arrangement.
Therefore, streak patterns or other undesired machining
marks can be prevented from remaining at the workpiece
surface.
REFERENCE SIGNS LIST

[0060]

1 control device
2 display device
3 CAD unit
4 input device
11 mesh preparation part
12 machining sequence setting part
13 data converting part
21 dimple image
50 machine body
54 tool
54a cutting blade
60 workpiece surface
61 dimple
610 virtual dimple
PA tool path

Claims

1. A machining method of a workpiece making a rotary tool having a cutting blade for intermittently cutting a workpiece surface move relative to the workpiece to machine the workpiece surface, including:
   a first step of determining a pattern of arrangement of a plurality of dimples at the workpiece surface formed after cutting by the cutting blade;
   and
   a second step of determining a tool path of the rotary tool so that the plurality of dimples are arranged at the workpiece surface in accordance with the pattern of arrangement determined at the first step.

2. The machining method of a workpiece according to claim 1, wherein the first step includes determining a shape and size of the plurality of dimples.

3. The machining method of a workpiece according to claim 1 or 2, wherein the second step includes successively connecting a plurality of machining points corresponding to the plurality of dimples to determine the tool path and determining an amount of rotation of the rotary tool between the machining points.

4. The machining method of a workpiece according to claim 3, further including a third step of making the rotary tool rotate while making the rotary tool move relatively along the tool path, wherein the third step controls an amount of feed and rotational phase of the rotary tool so that the rotary tool rotates by just one blade’s worth of angle between the machining points.

5. The machining method of a workpiece according to any one of claims 1 to 4, wherein the first step includes determining the pattern of arrangement of the plurality of dimples in a machining area including a first machining area machined by a first machining pattern and a second machining area machined by a second machining pattern and adjoining the first machining area.

6. A tool path generating device generating a tool path for machining a workpiece surface with a rotary tool having a cutting blade for intermittently cutting the workpiece surface, comprising:
   a dimple setting part setting a pattern of arrangement of a plurality of dimples at the workpiece surface formed after cutting by the cutting blade; and
   a path generating part generating a tool path of the rotary tool so that the plurality of dimples are arranged at the workpiece surface in accordance with the pattern of arrangement set at the dimple setting part.

7. A machine tool machining a workpiece surface with a rotary tool having a cutting blade for intermittently cutting the workpiece surface, comprising:
   a tool path generating device according to claim 6; and
   a machine body making the rotary tool rotate while moving the rotary tool relative to the workpiece in accordance with a tool path generated by the tool path generating device so as to machine the workpiece surface.

8. A tool path generating program making a computer generate a tool path for machining a workpiece surface with a rotary tool having a cutting blade for intermittently cutting the workpiece surface, the tool path generating program making the computer run a first routine of setting a pattern of arrangement of a plurality of dimples at the workpiece surface formed after cutting by the cutting blade; and
   a second routine of generating a tool path of the rotary tool so that the plurality of dimples are arranged at the workpiece surface in accordance with the pattern of arrangement set at the first routine.
FIG. 5
FIG. 11

1. START

2. READ DATA

3. PREPARE MESH

4. DISPLAY DIMPLE IMAGE

5. CONFIRM IMAGE?
   - Y: SELECT IMAGE?
     - Y: STORE MACHINING POINTS PO
     - N: END SELECTION?
       - Y: GENERATE MACHINING PROGRAM
       - N: END
FIG. 14

AR1 (FIRST MACHINING AREA) -- AR2 (SECOND MACHINING AREA)
INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2012/058658

B23Q15/00

A. CLASSIFICATION OF SUBJECT MATTER

B23Q15/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B23Q15/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched


Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Relevant to claim No.</th>
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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search

28 June, 2012 (28.06.12)

Date of mailing of the international search report

10 July, 2012 (10.07.12)

Name and mailing address of the ISA/

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### INTERNATIONAL SEARCH REPORT

**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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