Patent Document 2: JP-A 2010-110851

Patent Document 3: JP-A 2010-110966

Patent Document 4: JP-A 2011-156655

Patent Document 5: JP-A 2011-156863

Patent Document 6: JP-A 2012-000708 (US 2011/0312255 A1)

DISCLOSURE OF INVENTION

Embodiments of the invention seek to provide a method for cutoff machining a rare earth sintered magnet block having a substantial height into a multiplicity of pieces at a high accuracy, by using a plurality of thin cutoff abrasive blades having a reduced effective diameter, while controlling formation of a step between cutoff surfaces.

Embodiments of the invention are directed to a method for multiple cutoff machining a rare earth sintered magnet block using a multiple blade assembly comprising a plurality of cutoff abrasive blades coaxially mounted on a rotating shaft at axially spaced apart positions, each blade comprising a core in the form of a thin disk and a peripheral cutting part on the outer periphery of the core. The cutoff abrasive blades are rotated and fed to cutoff machine the magnet block into a multiplicity of pieces. The inventors have found that the object is achievable by setting the multiple blade assembly such that it is movable parallel to the plane of rotation of the blades, rotating and feeding the blades, starting the machining operation of the magnet block on one side to form cutting grooves in the magnet block, interrupting the machining operation before the magnet block is cut into pieces, moving the multiple blade assembly to the other side of the magnet block parallel to the plane of rotation of the blades, with the magnet block kept fixed, restarting the machining operation of the magnet block on the other side to form cutting grooves in the magnet block until the cutting grooves formed from the one side and the other side merge with each other, thereby cutting the magnet block into pieces. Then a rare earth sintered magnet block having a substantial height can be cutoff machined or sawn into a multiplicity of pieces at a high accuracy and productivity, by using the multiple blade assembly comprising a plurality of thin cutoff abrasive blades having a reduced effective diameter, and feeding the multiple blade assembly parallel to the plane of rotation of the blades, without a need for alignment of the magnet block, while controlling formation of a step between cutoff surfaces.

In the multiple cutoff machining of a rare earth sintered magnet block, the one side and the other side of the magnet block are preferably opposite sides in a horizontal direction. More preferably, the magnet block at its upper and lower surfaces is clamped by a fastening jig. Further preferably, the fastening jig includes a first clamp on which the magnet block is rested, a second clamp disposed on the magnet block, and a press unit for pressing the first and second clamps to apply a pressing force to the magnet block from one or both of its upper and lower sides. A portion of one clamp (or both clamps) which is disposed adjacent to the magnet block is provided with a generally horizontal channel extending inward from a position corresponding to a work surface of the magnet block, to define a resilient cantilever, whereby the magnet block is held between the first and second clamps by the repulsion force created by vertical movement of the resilient cantilever. Although the magnet block is susceptible to cracking or chipping upon application of a noticeable force because of its construction, the jig ensures that the magnet block is vertically held within the fastening jig in a tight, flexible manner. This further contributes effectively to high-accuracy machining when the magnet block is machined on the one side or the other side in horizontal direction.

Accordingly, in one aspect, the present invention provides a method for multiple cutoff machining a rare earth sintered magnet block using a multiple blade assembly comprising a plurality of cutoff abrasive blades coaxially mounted on a rotating shaft at axially spaced apart positions, each blade comprising a core in the form of a thin disk and a peripheral cutting part on the outer periphery of the core, said method comprising advancing the blade assembly and rotating the blades to machine the magnet block into mutiple pieces,

the method further comprising the steps of:

setting the multiple blade assembly on one side of the magnet block such that it is movable parallel to the plane of rotation of the blades,

rotating the blades,

starting the machining operation of the magnet block on one side to form cutting grooves in the magnet block,

interrupting the machining operation before the magnet block is cut through into pieces,

moving the multiple blade assembly to the other side of the magnet block parallel to the plane of rotation of the blades, keeping the magnet block kept fixed, and

restarting the machining operation of the magnet block on the other side to form cutting grooves in the magnet block until the cutting grooves formed from the one side and the other side meet each other, thereby cutting the magnet block into pieces.

In a preferred embodiment, the one side and the other side of the magnet block are opposite sides in horizontal direction.

More preferably, in each of the machining operation of the magnet block on the one side and the machining operation of the magnet block on the other side, the magnet block is cutoff machined while the cutoff abrasive blades are vertically fed.

In a preferred embodiment, the magnet block at its upper and lower surfaces is clamped by a fastening jig whereby the magnet block is secured within the fastening jig, and the position of the fastening jig is fixed whereby the position of the magnet block is fixed.

In a more preferred embodiment, the fastening jig includes a first clamp on which the magnet block is rested, a second clamp disposed on the magnet block, and a press unit for pressing the first and second clamps to apply a pressing force to the magnet block from one or both of its upper and lower surfaces. A portion of at least one clamp which is disposed adjacent to the magnet block is provided with a generally horizontal channel extending inward from a position corresponding to a work surface of the magnet block, to define a resilient cantilever, whereby the magnet block is held between the first and second clamps by the repulsion force created by vertical movement of the resilient cantilever.

In a preferred embodiment, the portion of at least one clamp which is disposed adjacent to the magnet block is partially raised to form pads near positions corresponding to opposite work surfaces of the magnet block so that the clamp contacts only at its pads with the opposing surface of the magnet block.

In a preferred embodiment, the portion of at least one clamp which is disposed adjacent to the magnet block is provided with rims at positions corresponding to opposite work surfaces of the magnet block, the rims being engaged with the magnet block for preventing the magnet block from separating apart.

In a preferred embodiment, only the first clamp is provided with the resilient cantilever, and the surface of the second clamp which is disposed adjacent to the magnet block is flat so that the second clamp is in plane contact with the entire opposing surface of the magnet block.

In a preferred embodiment, on each of the one and other sides of the magnet block, the multiple blade assembly is vertically fed from the first clamp side to the second clamp side, thereby sawing the magnet block into pieces.

In a preferred embodiment, the cutoff abrasive blades are rotated such that the rotational direction of the blades is reverse to the feed direction of the blades at the cutting points of the blades during the machining operation.

ADVANTAGEOUS EFFECT OF INVENTION

Using a plurality of thin cutoff abrasive blades having a reduced effective diameter, a rare earth sintered magnet block having a substantial height can be sawn into a multiplicity of pieces at a high accuracy. The invention may also be effective for controlling formation of a step on cutoff surface.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view illustrating one exemplary multiple blade assembly used in the invention.

FIGS. 2A to 2F are elevational views schematically illustrating one exemplary multiple cutoff machining method according to the invention, FIG. 2A showing the multiple blade assembly placed on one side of the magnet block, FIG. 2B showing the step of machining the magnet block on the one side, FIG. 2C showing the completion of machining of the magnet block on the one side, FIG. 2D showing the multiple blade assembly moved to the other side of the magnet block, FIG. 2E showing the step of machining the magnet block on the other side, and FIG. 2F showing the completion of machining of the magnet block on the other side.

FIGS. 3A to 3C illustrate one exemplary multiple blade assembly combined with a coolant feed nozzle, FIG. 3A being an elevational front view, FIG. 3B being an elevational side view, and FIG. 3C being a bottom view of the nozzle showing slits.

CLAIMS:

1. A method for multiple cutoff machining a rare earth sintered magnet block using a multiple blade assembly comprising a plurality of abrasive blades coaxially mounted on a rotating shaft at axially-spaced positions, each said blade comprising a core in the form of a thin disk and a peripheral cutting part on the outer periphery of the core, and said method comprising advancing the blade assembly and rotating the blades to machine the magnet block into multiple pieces, said method comprising the steps of:

setting the multiple blade assembly on one side of the magnet block such that it is movable parallel to the plane of rotation of the blades,

rotating the blades,

starting the machining operation of the magnet block on the one side to form cutting grooves in the magnet block,

interrupting the machining operation before the magnet block is cut through into pieces,

moving the multiple blade assembly to the other side of the magnet block parallel to the plane of rotation of the blades, keeping the magnet block fixed, and

restarting the machining operation of the magnet block on the other side to form cutting grooves in the magnet block until the cutting grooves formed from the one side and the other side meet each other, thereby cutting the magnet block into pieces.

2. A method of claim 1 wherein the magnet block is fixed with said one side and said other side horizontally opposite.

3. A method of claim 2 wherein in each of the machining operation of the magnet block on the one side and the machining operation of the magnet block on the other side, the magnet block is cutoff machined while the cutoff abrasive blades are advanced vertically.

4. A method of claim 2 or 3 wherein the magnet block is clamped by a fastening jig at its upper and lower surfaces whereby the magnet block is secured within the fastening jig,

and the position of the fastening jig is fixed whereby the position of the magnet block is fixed.

5. A method of claim 4 wherein the fastening jig includes a first clamp on which the magnet block is rested, a second clamp disposed on the magnet block, and a press unit for pressing the first and second clamps to apply a pressing force to the magnet block from one or both of its upper and lower surfaces, and
a portion of at least one clamp which is disposed adjacent to the magnet block is provided with a generally horizontal channel extending inward from a position corresponding to a work surface of the magnet block, to define a resilient cantilever.

6. A method of claim 5 wherein the portion of at least one clamp which is disposed adjacent to the magnet block is partially raised to form pads near positions corresponding to opposite work surfaces of the magnet block so that the clamp contacts only at its pads with the opposing surface of the magnet block.

7. A method of claim 5 or 6 wherein the portion of at least one clamp which is disposed adjacent to the magnet block is provided with rims at positions corresponding to opposite work surfaces of the magnet block, the rims being engaged with the magnet block for preventing the magnet block from separating.

8. A method of any one of claims 5 to 7 wherein only the first clamp is provided with the resilient cantilever, and the surface of the second clamp which is disposed adjacent to the magnet block is flat so that the second clamp is in plane contact with the entire opposing surface of the magnet block.

9. A method of claim 8 wherein on each of the one and other sides of the magnet block, the multiple blade assembly is vertically fed from the first clamp side to the second clamp side.

10. A method of claim 9 in which the multiple blade assembly is fed upwardly for the cutting on each of said one and other sides.

11. A method of any one of claims 2 to 10 wherein the cutoff abrasive blades are rotated such that during the machining operation the rotational direction of the blades at the cutting points of the blades is opposite to the feed direction of the blades.