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(54) **MACHINING METHOD AND MACHINING DEVICE HAVING HIGH EFFICIENCY AND LOW DAMAGE**

(57) Disclosed are a machining method and a machining device improving machining efficiency and preserving workpiece surface integrity. The machining method improving machining efficiency and preserving workpiece surface integrity includes: setting a workpiece (300) and a machining unit (400); and machining the workpiece (300) by the machining unit (400) at a preset machining speed, wherein the preset machining speed is not lower than a machining speed corresponding to the embrittlement of the workpiece material. The machining device improving machining efficiency and preserving workpiece surface integrity is used for executing the machining method having the same merits. The machining device includes: a base (100) used for mounting the workpiece (300) and the machining unit (400), and a driving unit (200) connected to the machining unit (400) and used for driving the machining unit (400) to the preset machining speed. By the machining method, the machining speed of the machining unit (400) is set during machining, which results in "skin effect" of subsurface damage caused by the embrittlement of the workpiece material (300) and enables the damage depth of the workpiece (300) to be confined in a shallow subsurface layer, so that the damage depth of the workpiece (300) is reduced, the workpiece integrity is preserved, and the machining quality and the machining efficiency are improved.

DRAWINGS

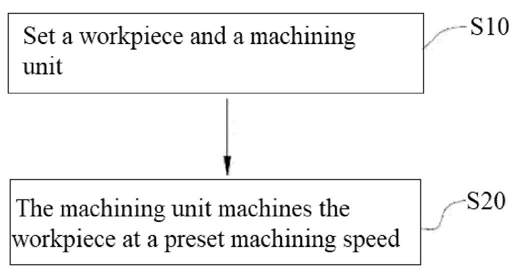

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to the technical field of material machining, and in particular, to a machining method and a machining device improving machining efficiency and preserving workpiece surface integrity.

BACKGROUND

[0002] Materials, such as ductile materials, hard and brittle materials, and composite materials, have good mechanical and physical properties, and are widely used in the fields of aerospace, defense, semiconductors, automobiles, cutting tools, and the like. The abovementioned materials are difficult to machine, and have the defects of low machining efficiency, low precision, and poor surface quality during machining.

SUMMARY

[0003] The present disclosure aims to solve at least one of the technical problems in the prior art. In view of this, the present disclosure provides a machining method that can have a high efficiency and simultaneously preserve surface integrity of a workpiece during machining.

[0004] The present disclosure further provides a machining device for executing the machining method that can have a high efficiency and simultaneously preserve surface integrity of a workpiece.

[0005] In a first aspect, one embodiment of the present disclosure provides a machining method improving machining efficiency and preserving workpiece surface integrity, which includes:

setting a workpiece and a machining unit; and
machining the workpiece by the machining unit at a preset machining speed, where the preset machining speed is not lower than the machining speed corresponding to the embrittlement of the workpiece.

[0006] The machining method improving machining efficiency and preserving workpiece surface integrity in the embodiment of the present disclosure at least has the following beneficial effects.

[0007] In the embodiment of the present disclosure, the workpiece is machined by the machining unit at the preset machining speed, which results in the embrittlement of the workpiece material, causes the "skin effect" of subsurface damage, and enables the damage depth of the workpiece to be in a shallow subsurface layer. As a result, the damage depth of the workpiece is reduced, the workpiece surface integrity is preserved, and the machining quality and the machining efficiency are improved.

[0008] According to the machining method improving machining efficiency and preserving workpiece surface integrity of some other embodiments of the present disclosure, the preset machining speed is that corresponding to the embrittlement of a material or the ductile matrix component in a composite material, or is not less than 150 m/s.

[0009] According to the machining method improving machining efficiency and preserving workpiece surface integrity of some other embodiments of the present disclosure, the workpiece is machined in one or more forms of grinding, turning, and milling.

[0010] According to the machining method improving machining efficiency and workpiece surface integrity of some other embodiments of the present disclosure, the workpiece is machined repeatedly for a plurality of times, and the machining depth of the machining unit is different each time.

[0011] According to the machining method improving machining efficiency and workpiece surface integrity of some other embodiments of the present disclosure, the workpiece is machined repeatedly for a plurality of times, and the machining depth of the machining unit is gradually reduced time by time.

[0012] According to the machining method improving machining efficiency and workpiece surface integrity of some other embodiments of the present disclosure, the workpiece is machined repeatedly for a plurality of times, and the particle size of the machining unit is gradually reduced step by step.

[0013] According to the machining method improving machining efficiency and workpiece surface integrity of some other embodiments of the present disclosure, ultrasonic vibration is performed while machining the workpiece.

[0014] In a second aspect, one embodiment of the present disclosure provides a machining device improving machining efficiency and preserving workpiece surface integrity, which is used for executing the machining method having the same merits. The machining device includes:

a base, used for mounting the workpiece and the machining unit; and
a driving unit, connected to the machining unit and used for driving the machining unit to the preset machining speed.

[0015] The machining device improving machining efficiency and preserving workpiece surface integrity in the embodiment of the present disclosure at least has the following beneficial effects.

[0016] In the embodiment of the present disclosure, the machining speed of the machining unit is increased through power driving of the driving unit to the machining unit, so that the damage depth of the workpiece is confined in a shallow subsurface layer, and the damage depth of a machined workpiece subsurface is reduced, thereby improving the machining quality of the workpiece.

[0017] According to the machining device improving machining efficiency and workpiece surface integrity of some other embodiments of the present disclosure, the machining device further includes an ultrasonic unit. The ultrasonic unit is connected to the machining unit, so that the machining unit performs ultrasonic vibration.

[0018] According to the machining device improving machining efficiency and preserving workpiece surface integrity of some other embodiments of the present disclosure, the machining device further includes a detection element used for detecting the machining speed of the machining unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIG. 1 is a schematic flowchart of a material machining method in the embodiments of the present disclosure;
FIG. 2 illustrates fitting curves of material strain-rates and material brittleness changes;
FIG. 3 illustrates fitting curves of material strain-rates and material damage depths; and
FIG. 4 is a structural schematic diagram of a material machining device in the embodiments of the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0020] The conception and the achieved technical effects of the present disclosure will be described below clearly and completely in combination with the embodiments, so as to fully understand the purposes, the features, and the effects of the present disclosure. Apparently, the described embodiments are merely part rather than all of the embodiments of the present disclosure. Based on the embodiments of the present disclosure, all other embodiments obtained by those skilled in the art without creative work belong to the scope of protection of the present disclosure.

[0021] In the description of the present disclosure, if orientation description is involved, for example, orientations or positional relationships indicated by "upper", "lower", "front", "rear", "left ", "right", etc. are orientations or positional relationships shown based on the accompanying drawings, they are merely used for the convenience of describing the present disclosure and simplifying the description, rather than indicating or implying that the devices or elements must have particular orientations, and constructed and operated in particular orientations. Thus, it cannot be construed as a limitation to the present disclosure.

[0022] In the description of the embodiments of the present disclosure, if a certain feature is called "arranged", "fixed", "connected", or "mounted" on another feature, it can be directly arranged, fixed, or connected to another feature, or can also be indirectly arranged, fixed, connected, or mounted on another feature. In the description of the present disclosure, if "a plurality of" is involved, it means more than one; if "multiple" is involved, it means more than two; if "greater than", "less than", and "more than" are involved, it should be construed as excluding the number; and if "above", "below", and "within" are involved, it should be construed as including the number. If "first" and "second" are involved, it should be construed as distinguishing technical features, but cannot be construed as indicating or implying relative importance or implicitly indicating the number of indicated technical features or implicitly indicating the precedence relationship of the indicated technical features.

[0023] Referring to FIG. 1, the embodiments of the present disclosure provide a machining method improving machining efficiency and preserving workpiece surface integrity, which includes the following machining steps:

first, a workpiece to be machined and a machining unit used for machining the workpiece are set; and then, the workpiece is machined by the machining unit at a preset machining speed, where the preset machining speed is not lower than the machining speed corresponding to the material embrittlement of the workpiece.

[0024] It should be noted that, during high-speed machining of a material, internal defects of the material are activated under an impact load, which results in the nucleation, propagation, and intersection of micro-cracks, and produces more cracks in a surface layer of the material, thereby resulting in the embrittlement of the material. The material resistance at the tip of a produced crack of the material will increase with the increase of a strain-rate, which hinders the propagation of the crack and reduces the damage depth, thereby resulting in the "skin effect" of subsurface damage caused by the embrittlement of the material. FIG. 2 lists fitting curves between the damage depths of several materials and the brittleness change of the materials. The horizontal coordinate axis is the brittleness change of the materials, and the longitudinal coordinate axis is the damage depths of the materials. It can be seen that the material brittleness increases along with the increase of the machining speed or the strain-rate, and the subsurface damage introduced by machining is only distributed in a shallow subsurface layer of the workpiece, so as to reduce the damage depth of the material during machining and improve the machining efficiency.

[0025] In addition, by fitting relation curves between the subsurface damage depths and the strain-rates of the materials, referring to FIG. 3, the horizontal coordinate axis represents the strain-rate of the material, and the longitudinal coordinate axis represents the subsurface damage depth of the material. In mathematical expression, the relationship between the subsurface damage depth and strain-rate of the material is:

$$\delta = k_1 . \left(\frac{d\varepsilon}{dt} \right)^{-0.34} \quad (1)$$

[0026] The relationship between the machining speed of the material and the strain-rate of the material is:

$$\frac{d\varepsilon}{dt} = k_2 . v \quad (2)$$

where, δ represents the damage depth, k_1 and k_2 are dimensionless parameters, $d\varepsilon / dt$ is the strain-rate of the workpiece material, and v is the machining speed of the workpiece.

[0027] It can be seen from Formula (2) that the strain-rate of the material is in direct proportion to the machining speed, and the strain-rate of the workpiece material is increased due to the increase of the speed of the machining unit. k_2 is related to the size of the material and the machining depth, and can be calculated by deriving a formula.

[0028] It can be seen from Formula (1) that the subsurface damage depth of the material is in direct proportion to a negative exponent of the strain-rate, that is, the subsurface damage depth of the workpiece decreases with the increase of the machining speed and gradually trends to the surface layer, so that the "skin effect" of subsurface damage of the workpiece is achieved. By increasing the machining speed, the subsurface damage of the workpiece can be reduced, the machining efficiency of the workpiece can be improved, and the machining quality can be ensured.

[0029] The damage "skin effect" is an inherent characteristic of an engineering material, that is, in a high strain-rate loading process of a workpiece, the damages (such as crack, dislocation, and phase change) and the like of the material are concentrated in a local loading regime without extensive propagation, so that the subsurface damage depth decreases with the increase of the machining speed or the strain-rate. In the present disclosure, the workpiece is machined at the preset machining speed, so as to reduce the subsurface damage depth. The preset machining speed is the machining speed corresponding to the embrittlement of the workpiece material. For a ductile material, the preset machining speed refers to the machining speed corresponding to the embrittlement thereof. For a hard and brittle material, the preset machining speed refers to the conventional high speed machining speed (the machining speed is over 150 m/s). For a composite material, the preset machining speed refers to the machining speed corresponding to the embrittlement of the ductile matrix component in the material.

[0030] The "skin effect" of the material damage exists in the machining of the hard and brittle material, the ductile material, the composite material, and the like. It should be noted that the present disclosure aims at the workpiece materials, including the hard and brittle material, the ductile material, the composite material, and the like. During the machining of hard and brittle materials, with the increase of the machining speed, the brittleness increases, the machining chips become smaller, the subsurface damage depth decreases. For the ductile material, the plastic deformation of the material is inhibited by machining at a high speed, the material is removed in a brittle fracture form, the temperature of a machining regime is suppressed, and the thickness of a metamorphic layer in the workpiece subsurface is reduced. During machining at a high speed, the material is in a high-strain-rate state. The embrittlement of the ductile material or the brittleness of the hard and brittle material can be improved due to the strain-rate hardening effect during the machining, so that the subsurface damage depth is reduced by the "skin effect" of the workpiece subsurface damage.

[0031] The machining speed corresponding to the embrittlement of a ductile material or the ductile matrix component in a composite material may be judged by observing the shapes of machining chips, the morphology of the chips, the workpiece surface hardening degree, the workpiece surface quality, and the like at different machining speeds (machining strain-rates), so as to identify that the material is in a plastic fracture state or a brittle fracture state. For example, during the machining of the ductile material, with the increase of the machining speed, the machining chips change from continuous to discontinuous, reflecting the characteristics of brittle fracture. At this moment, the workpiece material within the machining zone is embrittled, so that the machining state of the workpiece is characterized by the shapes of the chips.

[0032] In a general low-speed machining situation, the chip of a ductile material is typically continuous, while the chip of a brittle material is in a fragmented shape. With gradual increase of the machining speed, the ductile material will be embrittled, and the chips thereof are changed from continuous bands into a serrated or a fragmented shape. Taking 7050-T7451 aluminum alloy as an example, the aluminum alloy is a typical ductile material. When the aluminum alloy is machined at the cutting speed of 1,257 m/min, the chips are in an obvious serrated shape. At this moment, the aluminum alloy is embrittled.

[0033] The embrittlement of the workpiece material is related to the factors, such as the machining temperature of the workpiece, the machining load applied by the machining unit, the machining depth, the machining speed, the workpiece material, and the like. The machining speed corresponding to the embrittlement of the workpiece material may be experimentally obtained by fixing other parameters and adjusting the machining speed of the machining unit.

[0034] The machining unit and/or the workpiece may also be positioned before the workpiece is machined, so that the machining unit performs machining at a preset machining depth and a corresponding machining position of the workpiece, so as to ensure the machining accuracy. The machining mode of the abovementioned machining unit on the workpiece may be selected according to a specific machining process of the workpiece, such as grinding, turning, and milling. The type of the machining unit may also be selected according to a specific machining process of the workpiece, such as a grinding wheel, a turning tool, a milling tool. The machining speed of the machining unit may refer to the moving speed and the feeding speed of the machining unit relative to the workpiece, the rotating speed of the machining unit, and the like.

[0035] The machining mode of the workpiece by the machining unit may adopt a mode that the machining unit moves or rotates or moves and rotates relative to the workpiece. For example, the machining unit is set as the milling tool, the milling tool moves relative to the workpiece according to a predetermined trajectory, so as to realize the milling of the workpiece; or the machining unit is set as the turning tool, the turning tool feeds gradually relative to the workpiece, so as to realize the turning of the workpiece; or the machining unit is set as the grinding wheel which applies a continuous grinding force to the workpiece while rotating and moving relative to the workpiece, so as to realize the material removal of the workpiece. The application range of the machining method provided by the embodiments of the present disclosure is wide, and a corresponding machining mode may be selected to machine the workpiece according to different machining requirements.

[0036] The machining depth of the workpiece has an upper limit. When the machining depth of the workpiece is great, if a preset machining depth is reached by only performing single machining, the damage degree of the workpiece is serious, and the machined workpiece is also easily damaged. In order to meet the process requirements of the machining depth and the machining quality at the same time, the workpiece needs to be machined circularly for a plurality of times and gradually feeds to a preset thickness.

[0037] Specifically, a single machining depth is set to machine the workpiece time by time until the preset machining depth is reached according to the machining depth requirement of the workpiece. The single machining refers to that the machining unit completes the machining of the whole surface to be machined of the workpiece on the premise of the preset machining depth of this time. According to the characters of the material and specific machining requirements, different machining depths may be set for the machining unit each time, so that the machining depth adapts to the machining situation of the workpiece of this time, and the workpiece machining flexibility is improved. Following the principle of rough machining before finish machining, a great machining depth may be set first, and the machining depth may be reduced step by step with the increase of machining times, so as to reduce the workpiece damage depth and improve the quality of the workpiece surface on the premise of ensuring that the workpiece has sufficient machining depth. In addition, different machining depths may be executed by selecting different machining workpieces, for example, the workpiece is ground after being cut by a certain thickness by using a cutting tool, which takes both the machining efficiency and the machining quality into consideration.

[0038] In actual production, machining units with different particle sizes and hardness may be selected to machine the workpiece according to the specific machining requirements of the workpiece. The particle size refers to the size of the particles in the machining unit for performing main machining on the workpiece. The smaller the particle size of the machining unit, the smaller the damage depth of the workpiece. The machining unit with a larger particle size can realize the rough machining of the workpiece, and can quickly eliminate the defects on the workpiece surface or the damage caused in the previous process, so that the workpiece surface has certain flatness. The machining unit with a smaller particle size can realize the finish machining of the workpiece, ensure the integrity and the flatness of the workpiece surface, reduce subsequent machining processes, and shortens the machining time. In the present embodiment, the workpiece is machined repeatedly for a plurality of times, and the particle size of the machining unit is reduced step by step, so as to ensure the machining efficiency of the workpiece and the surface quality of the workpiece.

[0039] In order to further optimize the machining quality of the workpiece, the machining unit with the smaller particle size can be selected, so as to improve the machining speed of the machining unit. The machining speed does not exceed the machining speed corresponding to the embrittlement of the workpiece material, and a single machining depth is reduced, so as to realize high-efficiency and low-damage machining and improve the surface quality of the workpiece.

[0040] In another embodiment, during the machining of workpieces, an ultrasonic vibration unit is added, which can reduce the grinding force, improve the stability of a machining system, reduce a friction force between a cutting tool and the workpiece, reduce the generation of grinding heat, reduce or avoid a problem of burning of the workpiece surface, can also reduce the roughness of the workpiece surface, and improve the machining quality of the workpiece surface.

[0041] Referring to FIG. 4, the embodiments of the present disclosure further provide a machining device improving machining efficiency and preserving workpiece surface integrity. The machining device is used for executing the abovementioned material machining method. The material machining device includes a base 100 and a driving unit 200. The base 100 is used for mounting a workpiece 300 and a machining unit 400. The base 100 provides an operation platform for the movement of the machining unit 400 and the machining of the workpiece 300. The driving unit 200 is connected to the machining unit 400 and provides power support for the machining unit 400, so that the machining unit 400 machines the workpiece 300 at a preset machining speed.

[0042] The machining speed of the machining unit 400 is increased through power driving of the driving unit 200 to the machining unit 400, so that the damage depth of the workpiece 300 is confined in a surface layer, and high-efficiency and low-damage machining is realized. By limiting the machining speed of the machining unit 400, the workpiece 300 is prevented from brittle fracture, and the surface integrity of the workpiece 300 is affected.

[0043] The machining unit 400 may move and/or rotate relative to the workpiece 300. The driving unit 200 may be one or a combination of more of an electric machine, a motor, a cylinder, and the like, so as to realize the movement and/or rotation of the machining unit 400 relative to the workpiece 300. The type of the machining unit 400 may be selected according to actual use requirements, such as a grinding wheel, a turning tool, and a milling tool.

[0044] A fixture for clamping or fixing the workpiece 300 may be arranged on the base 100, so that the workpiece 300 is kept in a static state during machining, thereby improving the machining precision. The fixture may be a platform for providing a placement plane for the workpiece 300, or a fixture capable of adsorbing the workpiece 300, or a manipulator capable of clamping the workpiece 300, or the like. A plurality of workpieces 300 may be arranged on the fixture at one time, so that the machining unit 400 can machine the plurality of workpieces 300 at one time, thereby improving the machining efficiency of the machining device.

[0045] A first moving module 110 may also be mounted on the base 100. A clamp is mounted on the first moving module 110, and is driven to move through the first moving module 110, so as to facilitate the positioning between the machining unit 400 and the workpiece 300. Thus, the machining unit 400 may machine different areas of the workpiece 300. The first moving module 110 may be provided with not less than two groups of moving components. The extension directions of moving guide rails in different moving components are different, so that the position of the workpiece 300 can be adjusted in different directions.

[0046] A second moving module 120 may also be arranged on the base 100. The second moving module 120 may drive the machining unit 400 to move in the vertical direction, so that the machining unit 400 feeds close to the workpiece 300, or moves away from the workpiece 300 to avoid for the movement of the workpiece 300. The machining depth of the workpiece 300 by the machining unit 400 can be adjusted by moving the machining unit 400 in the vertical direction, so that the machining device adapts to different machining requirements. The second moving module 120 may also include a plurality of groups of moving components. The machining unit 400 is mounted on the moving components, and the position of the machining unit may be adjusted in a horizontal plane under the driving of the moving components, so as to realize the movement of the machining unit 400 relative to the workpiece 300, thereby enabling the machining unit 400 to machine different areas of the workpiece 300.

[0047] On the premise of meeting the moving requirement of the machining unit 400 and the workpiece 300, the abovementioned first moving module 110 and second moving module 120 may select the existing automatic or manual moving modules.

[0048] In another embodiment, an ultrasonic unit 130 is also arranged on the driving unit 200. The machining unit 400 forms ultrasonic vibration under the influence of the ultrasonic unit 130. The ultrasonic vibration assists in machining the workpiece 300 by the machining unit 400, which can effectively reduce or avoid the problem of surface burning of the workpiece 300, and improve the surface machining quality of the workpiece 300.

[0049] A detection element for detecting machining parameters of the machining unit 400 may also be arranged on the base 100, for example, a displacement sensor is arranged for detecting the machining depth of the machining unit 400, a pressure sensor is arranged for testing an acting force of the machining unit 400 applied to the workpiece 300, and a speed sensor is arranged for detecting the machining speed of the machining unit 400, so as to facilitate the acquisition of real-time machining parameters of the machining unit 400, thereby ensuring the machining precision of the workpiece 300.

[0050] The abovementioned machining device improving machining efficiency and preserving workpiece surface integrity may be applied to machining equipment, such as a turning machine, a milling machine, and a grinding machine, so as to enable the workpiece 300 to adapt to different machining requirements, and improve the machining quality of the workpiece 300 in different machining environments.

[0051] The embodiments of the present disclosure are described in detail in combination with the accompanying drawings above, but the present disclosure is not limited to the abovementioned embodiments. Within the scope of knowledge possessed by those of ordinary skill in the art, various changes can be made without departing from the purpose of the present disclosure. In addition, the embodiments of the present disclosure and the features in the embodiments may be combined with each other without conflict.

Claims

1. A machining method improving machining efficiency and preserving workpiece surface integrity, comprising:

    setting a workpiece and a machining unit; and
    machining the workpiece by the machining unit at a preset machining speed, wherein the preset machining speed is not lower than the machining speed corresponding to the embrittlement of the workpiece.

2. The machining method improving machining efficiency and preserving workpiece surface integrity according to claim 1, wherein the preset machining speed is the machining speed corresponding to the embrittlement of a material or the ductile matrix component in a composite material, or is not less than 150 m/s.

3. The machining method improving machining efficiency and preserving workpiece surface integrity according to claim 1, wherein the workpiece is machined in one or more forms of grinding, turning, and milling.

4. The machining method improving machining efficiency and workpiece surface integrity according to any one of claims 1 to 3, wherein the workpiece is machined repeatedly for a plurality of times, and the machining depth of the machining unit is different each time.

5. The machining method improving machining efficiency and workpiece surface integrity according to any one of claims 1 to 3, wherein the workpiece is machined repeatedly for a plurality of times, and the machining depth of the machining unit is gradually reduced time by time.

6. The machining method improving machining efficiency and workpiece surface integrity according to any one of claims 1 to 3, wherein the workpiece is machined repeatedly for a plurality of times, and the particle size of the machining unit is gradually reduced step by step.

7. The machining method improving machining efficiency and workpiece surface integrity according to any one of claims 1 to 3, wherein ultrasonic vibration is performed while machining the workpiece.

8. A machining device improving machining efficiency and preserving workpiece surface integrity, used for executing the machining method improving machining efficiency and workpiece surface integrity having the same merits according to any one of claims 1 to 7, comprising:

a base, used for mounting the workpiece and the machining unit; and
a driving unit, connected to the machining unit and used for driving the machining unit to the preset machining speed.

9. The machining device improving machining efficiency and workpiece surface integrity according to claim 8, further comprising an ultrasonic unit, wherein the ultrasonic unit is connected to the machining unit, so that the machining unit performs ultrasonic vibration.

10. The machining device improving machining efficiency and preserving workpiece surface integrity according to claim 8, further comprising a detection element used for detecting the machining speed of the machining unit.

DRAWINGS

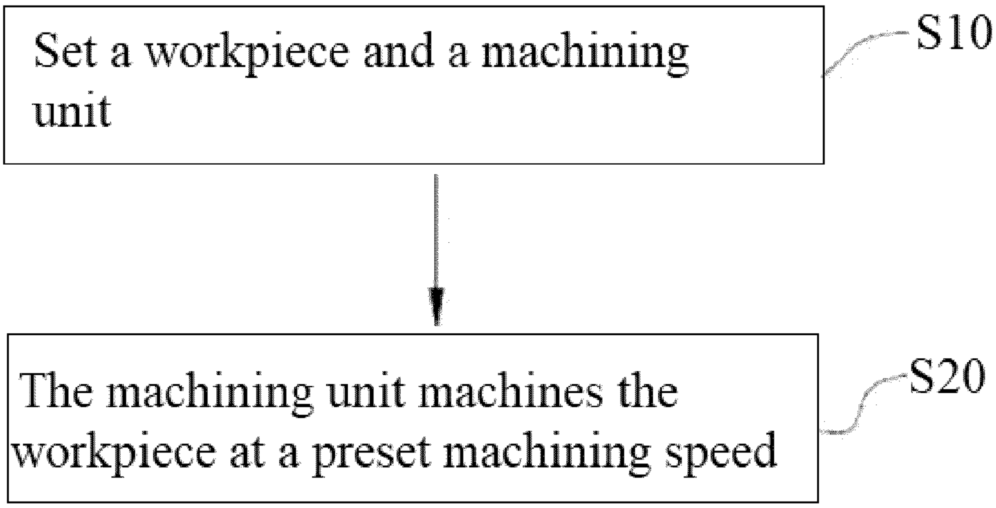
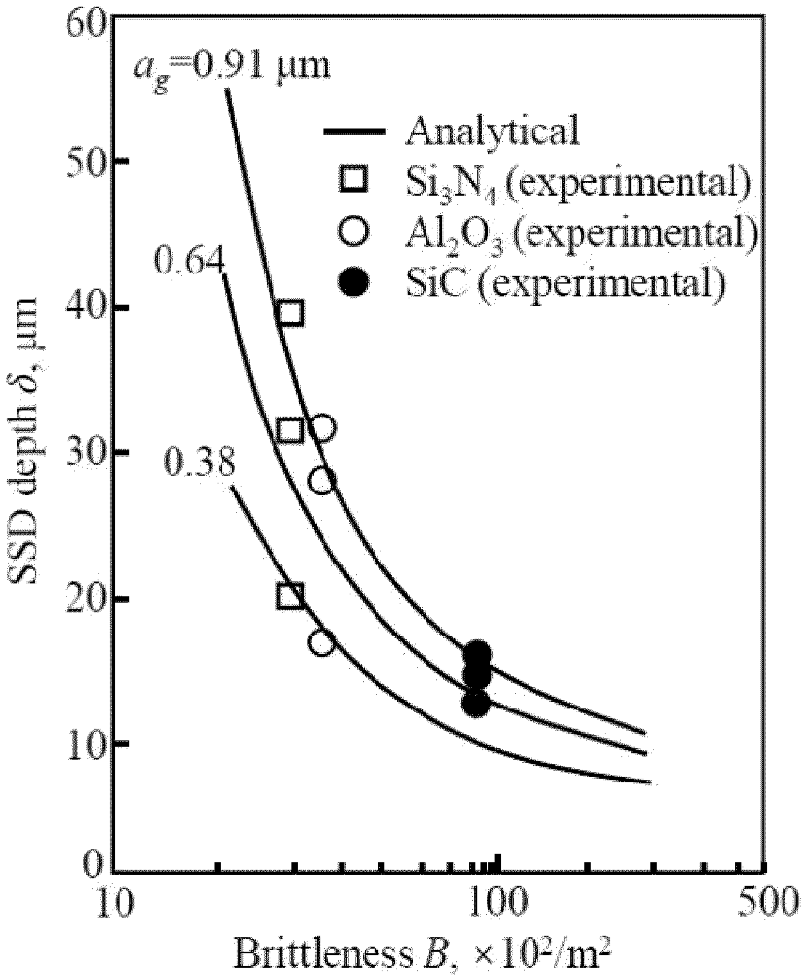
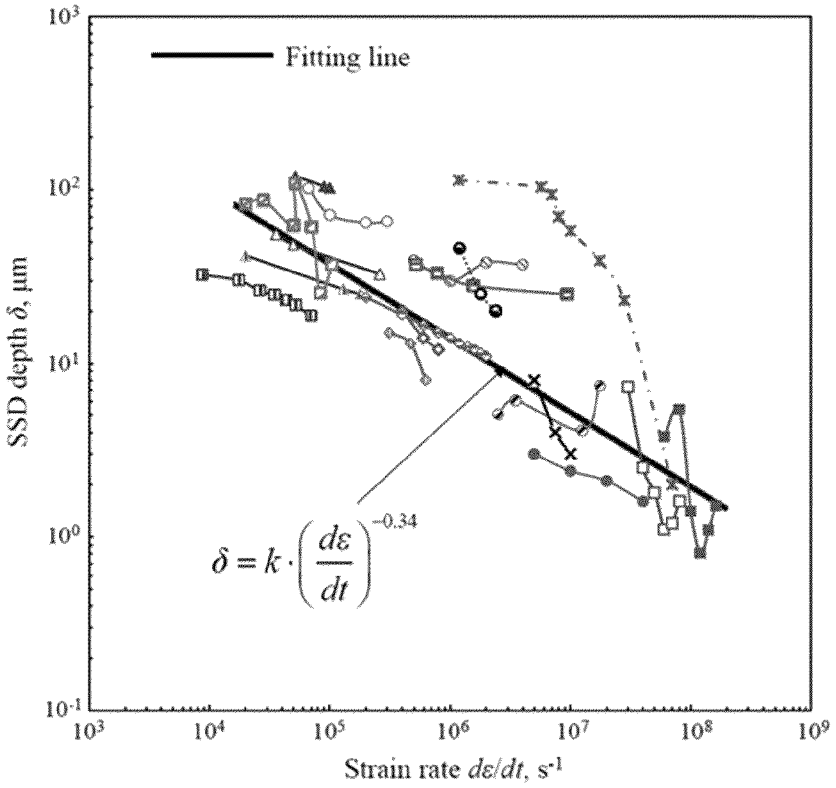


FIG. 1



60
50
40
30
20
10
0
a_g=0.91 µm
0.64
0.38
Analytical
Si_3N_4 (experimental)
Al_2O_3 (experimental)
SiC (experimental)
SSD depth δ, µm
10
100
500
Brittleness B, ×10²/m²

FIG. 2



Fitting line
SSD depth δ, μm
Strain rate dε/dt, s⁻¹
$\delta = k \cdot \left(\frac{d\varepsilon}{dt}\right)^{-0.34}$
10³
10²
10¹
10⁰
10⁻¹
10³
10⁴
10⁵
10⁶
10⁷
10⁸
10⁹

FIG. 3

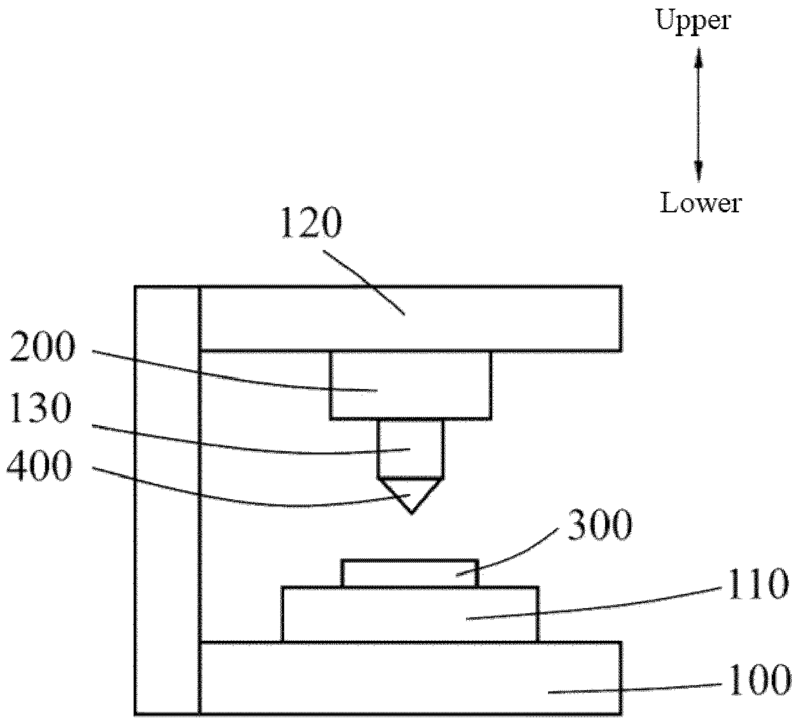


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No. **PCT/CN2020/132300**

A. CLASSIFICATION OF SUBJECT MATTER

B24B 1/00(2006.01)i; B24B 1/04(2006.01)i; B24B 49/00(2012.01)i; B23C 3/00(2006.01)i; B23P 13/00(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)

B24B; B23C; B23P

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)

EPODOC, WPI, CNPAT, CNKI: 南方科技大学, 铝合金, 塑性, 脆, 复合, 脆化, 趋肤, 加工速度, 切削速度, 多次, 二次, 粗, 精, 车, 铣, 磨, 切, 抛光, 超声, 振, aluminium w alloy, brittl+, embrittl+, mill+, grind+, cut+, polish+, speed, velocity, crack, fractur+, ultrasonic+, shak+, vibrat+, quak+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 111618665 A (SOUTH UNIVERSITY OF SCIENCE AND TECHNOLOGY) 04 September 2020 (2020-09-04) claims 1-10, description paragraphs 3-62, figures 1-4	1-10
X	CN 104625571 A (HUNAN UNIVERSITY OF SCIENCE AND TECHNOLOGY) 20 May 2015 (2015-05-20) description, paragraphs 21-31, figures 1-4	1-3
Y	CN 104625571 A (HUNAN UNIVERSITY OF SCIENCE AND TECHNOLOGY) 20 May 2015 (2015-05-20) description, paragraphs 21-31, figures 1-4	4-10
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Date of the actual completion of the international search	Date of mailing of the international search report
05 February 2021	**26 February 2021**

Name and mailing address of the ISA/CN

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