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Apparatus for metal working using a coolant fluid
Vorrichtung zur Metallbearbeitung unter Verwendung einer Kühlflüssigkeit
Appareil pour l’usinage des métaux à l’aide d’un fluide de refroidissement

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Description

[0001] The invention concerns a method and apparatus for grinding that employs a coolant fluid. In particular, it relates to an enhancement to a process called creep-feed grinding by means of which a very high stock removal rate is achieved.

[0002] Creep-feed grinding is a full depth or full cut operation that often allows a complete profile depth to be cut from a solid in a single pass. The workpiece to be machined is fixed to a surface table which is fed past the rotating grinding wheel at a constant speed. The stock removal rate is set by the size and number of chip cavities in the surface of the wheel in combination with a number of other factors. A high removal rate can be achieved, but the process can generate sufficient frictional heat to burn the workpiece surface and damage the wheel. Increasing the depth of wheel cut hitherto had required reduced workpiece feed rate or performing the operation in two or more passes.

[0003] Improvements have been found by providing adequate coolant flow to the wheel contact region ensuring workpiece coolant and grinding wheel coolant and efficient cleaning. It is well known to use jet cleaning nozzles delivering coolant close to the wheel surface in large volumes. The type and composition of the wheel is carefully chosen for the type of material to be ground for the most acceptable balance between stock removal rate and wheel wear.

[0004] Removal of metal material from a workpiece at higher rates can require a significant quantity of coolant that must be delivered precisely and in sufficient quantities at, and across the entire profile of, the interface between the metal working tool and the workpiece. Typically, the coolant nozzle is positioned manually by an operator based on experience and an estimate of an orientation and position that will deliver the coolant stream at the metalworking tool. The significant volume and pressure of the stream of coolant during a grinding operation, for example, floods the grinding compartment and obscures any view of the exact position of the coolant stream’s impact and of the machining interface. Often, if the coolant stream has not been precisely delivered to the machining interface, the machined workpiece will have flaws due to excessive heat buildup or material removal, and must be reworked or scrapped.

[0005] Therefore, further improvements are needed to ensure that an adequate stream of coolant is delivered precisely and in sufficient quantities across the profile of the machining interface between the metalworking tool and the workpiece.

[0006] FR 2 828 654 describes coherent jet nozzles for applying coolant in grinding applications and provided with a laser pointer.

[0007] The present invention relates to a metal machining apparatus for removal of metal from a workpiece, comprising: 1) a holder for a workpiece, 2) a metalworking tool that is configured to engage the workpiece along a machining interface to remove metal from the workpiece, 3) a coolant nozzle for emitting a stream of a coolant fluid, the nozzle comprising a nozzle body having a flow passage and a laser bore, wherein the flow passage has an inlet and an outlet, and the laser bore has a line of sight with the flow passage outlet, and 4) a visible laser removably inserted into the laser bore, that cooperates with the nozzle body for visually positioning the nozzle relative to the metalworking tool, whereby the emitted stream of coolant fluid can be directed at the machining interface.

[0008] The invention further relates to a laser-targeted coolant nozzle for use in applying coolant fluid to a machining apparatus for removal of metal from a workpiece at a machining interface, comprising: 1) a coolant nozzle body having a flow passage and a laser bore, wherein the flow passage has an inlet and an outlet, and the laser bore forms an access opening in the outer surface of the nozzle body and has a line of sight with the flow passage outlet, and 2) a visible laser removably inserted into the laser bore, that cooperates with the nozzle body for visually positioning the coolant nozzle relative to the machining apparatus, whereby the stream of coolant fluid can be directed at the machining interface.

[0009] Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a schematic diagram of a metalworking apparatus of the present invention, illustrated as a grinding wheel for removing metal from a workpiece, having a laser-targeted coolant nozzle with a visible light laser positioned therein.

Figure 2 shows the schematic diagram of Figure 1, showing the coolant nozzle emitting a stream of coolant fluid.

Figure 3 shows a cross sectional view through the laser-targeted coolant nozzle of the present invention, having a visible laser positioned therein.

Figure 4 shows the cross sectional view of the coolant nozzle of Fig. 2, where the visible laser has been removed and replaced with a seal plug.

Figure 5 shows a schematic diagram of an alternative laser-targeted coolant nozzle of the invention with the visible light laser positioned therein.

Figure 6 shows the schematic diagram of Figure 5, showing the coolant nozzle emitting a stream of coolant fluid.

[0010] A variety of metalworking tools can be used to remove material from a work piece. A typical metalworking tool for removing material is a grinder, more specifically a grinding wheel. The grinding wheel is used to remove material from a work piece based upon the profile
of the outer periphery of the wheel. A typical grinding wheel can have a flat profile or the profile can be curvilinear, rectilinear or a combination of both. Typically the profile of a cross section of the grinding wheel throughout its entire periphery is identical. The range of values of surface speed for the type of grinding wheel employed within which enhancement was achieved was from about 10 meters per second up to about 80 meters per second.

Figs. 1 and 2 show a metalworking assembly that includes a metalworking tool shown as a grinding wheel 2 rotating in the direction of arrow 4 to engage a workpiece 6 that can be moved into the rotating wheel 2 in the relative direction of arrow 8. The illustrated operation is known in the art as “down” grinding in a contact region of the grinding wheel. The invention is found to work just as well with “up” grinding. Essentially the process of the invention is a developed form of the process known as creep-feed grinding, although this may be regarded as something of a misnomer since the enhancement results is very much faster removal of workpiece material.

The grinding wheel 2 is mounted on a rotary spindle 10 carried by a tool head or chuck 12 which is part of a standard multi-axis machine. The workpiece 6 is secured in position for machining by means of a mounting fixture 14, illustrated as a pair of mounting brackets 14a and 14b, on a surface of a machining table 16. Since the invention is intended to be a “one-pass” grinding process, the width of the grinding wheel is configured to correspond to the width of the ground surface required. The workpiece is moved into and is machined by the rotating grinding wheel at a machining interface 19.

A typical grinding operation includes the grinding of the distal tips of a turbine blade used in a gas turbine engine.

During the grinding operation, as shown in Fig. 2, a stream 18 of liquid coolant, typically comprising a water-soluble oil, is emitted from and directed by nozzle 20 at the machining interface 19 on the periphery of wheel 2. The nozzle 20 is the outlet of a closed-loop coolant delivery, collection and filtration system. Spent coolant ejected from the wheel is collected in a sump (not shown), in the lower part of the machine, and drawn-off through an efficient filtration system to remove debris down to a particle size, typically of at least, about 10 micron.

Integral with the filtration system (not shown) is a high pressure pump system (also not shown) that delivers coolant under pressure to the inlet 28 of nozzle 20. As shown in Fig. 3, the coolant is supplied to the inlet 28 via a high pressure hose 31 to an inlet port 32 secured to the inlet 28, at a pressure of up to 100 bar, typically 70 bar, at a flow rate of up to about 60 liters per minute.

The coolant nozzle emits a stream of coolant at a high velocity and pressure. During the grinding operation, the coolant stream impinges the grinding wheel at great velocity. The resulting collision of the high-velocity coolant stream with the high-speed rotating grinding wheel causes the impinging coolant fluid to splash and splatter in all directions, creating a cloud of coolant mist and droplets that obstructs nearly completely the visibility of the machining operation.

Nevertheless, precise targeting of the stream of coolant to the machining interface can be important to achieving effective and accurate grinding. If the coolant is not properly directed to all necessary portions of the grinding wheel, faulty grinding can result from over-heating of and excessive metal removal from the workpiece.

Since the high speeds of the operation prevent aiming or directing the coolant stream at the targeted portion of the grinding wheel, after the grinding operation has begun, the present invention was developed to accurately position the nozzle assembly, prior to starting the coolant stream and the grinding operation. FIG. 1 shows the metalworking assembly prior to the start of the grinding operation. To ensure that the nozzle 20 will direct the stream of coolant 18 (shown in FIG. 2) at the proper location on the grinding wheel 2, shown as machining interface 19, the nozzle 20 is configured with a laser bore 22 within which a visible light laser 40 can be positioned. The laser bore 22 is configured to accept and removably secure the laser 40 in a stationary position. In its stationary position, the visible laser 40 can emit a beam of visible light along a line 23.

The laser bore 22 is configured within the nozzle 20 for cooperative positioning of laser device 40 with the outlet 29. More specifically, the laser light beam emitted along line 23 cooperates with a stream reference point 25 on the periphery of the outlet 29, to provide a targeting means for visually positioning and directing the subsequent stream of coolant 18 from the nozzle 20 at the grinding wheel 2. Typically, the metalworking operation requires that the profile of the emitted stream 18 of coolant registers with the machining interface 19 on the periphery of the grinding wheel 2. To ensure proper orientation of the nozzle and registration of the profile of the coolant stream with the profile of the machining interface, the machining interface 19 will have a profile having at least one machining reference point 15. Typically, the machining reference point 15 and the stream reference point 25 are positioned upon the profiles of their respective machining interface 19 and nozzle outlet 29 in a cooperating and substantially similar location. The machining reference point 15 is selected whereby, when the visible light beam along line 23 emitted from the laser-targeted nozzle 20 is registered with or lies upon the machining reference point 15, the coolant nozzle 20 is properly targeted and oriented for the subsequent metalworking operation.

As shown in Fig. 1, the nozzle 20 having the laser 40 inserted into the laser bore 22, is positioned manually, whereby the visible laser beam along line 23 passes through or along both the stream reference point 25 to the machining reference point 15. In this position, the coolant nozzle has been properly and optimally pre-positioned for the subsequent metalworking operation. The pre-positioned and targeted coolant nozzle is then as-
A typical laser-targeted coolant nozzle is shown in cross-section in Figure 3. The coolant nozzle 20 comprises a nozzle body having an inlet 28, outlet 29, and a flow passage 27 connecting the inlet with the outlet. The geometry of the inlet 28, the inner surface of the fluid passage 27, and the outlet 29 are configured to provide the profiled pattern of the emitted coolant stream 18 (shown in Fig. 2). Design criteria can include configuring the interior surface of the fluid passage to limit turbulence of the fluid as it passes through the nozzle, thereby causing the flowing coolant to conform to a particular coolant stream profile. In one embodiment, the nozzle is configured to pass the coolant liquid there through in laminar flow as the coolant passes through and exits the nozzle. [0027] The coolant nozzle 20 has a body 21 having a laser bore 22 that forms an opening 24 through an outer surface 26 of the nozzle body, which is in fluid communication with the flow passage 27. The laser bore 22 is typically tapered toward and intersects at an interface 30 with the coolant flow passage 27 of the nozzle 20. The laser bore 22 is configured to receive a laser device 40, as shown in Figs. 1 and 3.

[0028] Typically the nozzle 20 is configured for removal of the laser 40 from the laser bore 22, and for insertion of a removable plug 50 into the laser bore 22 during the grinding operations, as shown in Figs. 2, 4 and 6. Typically the removable plug 50 will have a distal end 52 that projects through the laser bore 22. The distal end 52 of the removable plug 50 typically has a plug face surface 56 that cooperates with the inner surface of the flow passage 27 of the nozzle 20 along an interface 30 between the flow passage 27 and the laser bore 22. The plug face surface 56 mimics the shape of the inner surface of the flow passage 27 that had been removed when the laser bore 22 was formed in the nozzle body 21.

[0029] The laser bore 22 is configured to provide at least one line of sight from the laser bore 22 to the flow passage outlet 29. Typically the laser bore 22 and the laser device 40 are of a cylindrical shape, although other shapes can be used. Likewise, the plug 50 has a body portion 51 of substantially the same shape as the laser, and is configured to conform to a seal (not shown) disposed in the laser bore 22. The plug 50 will typically have a means of engaging the inner surface of the laser bore 22, such as a set of threads 58 that mate with corresponding threads 38 in the laser bore 22. For ease of removal, the plug 50 will typically have a handle 59 on a proximal end 54 that extends from the nozzle body for easy insertion and removal of the plug.

[0030] A typical coolant nozzle of the present invention is available from Innatech, LLC of Rochester, MI.

[0031] The laser device 40 can be any laser which emits a visible laser beam. The color and size of the emitted laser beam can be any kind which is visible from a distance of less than about 2 meters. Typically the laser is a red diode laser for emitting a visible red laser beam. The laser can be self-powered, such as with batteries and a manual on-off switch, or can be powered and controlled through a power cord to a remote electrical power source.

[0032] A typical example of a visible laser is the MLM
(3/4 inch diameter), available from FP Industries, Caba-
no, Quebec, Canada.

[0033] It is also disclosed a method of using a visible laser to align a coolant stream emitted from a nozzle to-
ward the machining interface of a metal cutting tool when performing a working operation on a work piece. In a
typical method, a work piece is secured in a holder on the table of a metal grinding apparatus. The work piece and a
rotating grinding tool are configured for engage-
ment at a machining interface to remove metal from the
work piece. The machining interface has a specific inter-
face profile that conforms to the profile of the outer pe-
riphery of the grinding wheel, and will form the machine
profile on the work piece when completed. The position-
ning movement of the work piece and the grinding tool
relevant to one another is typically controlled by a com-
puterized controller. A nozzle for directing a stream of
coolant fluid is mounted to provide the stream of coolant
fluid at the machining interface during the metalworking
operation. The nozzle is configured to provide a laser
bore into which a visual laser can be inserted for purposes
of positioning the nozzle. The operator will insert the vis-
ible laser prior to operation, the visible laser will cooperate
with the nozzle whereby the directing and positioning of
the laser beam emitted from the laser will indicate the
destination of the resulted coolant stream that is dis-
charged from the flow nozzle during operation. The laser
beam is configured to accurately reproduce the orienta-
tion of the coolant stream that will be emitted from the
positioned coolant nozzle. After the nozzle is properly
oriented and positioned, and secured in place, the oper-
ator removes the laser device from the laser bore, and
inserts the plug that seals the laser bore during the grind-
ing operation, preventing coolant fluid from leaking out
of the coolant nozzle during operation. At any time the
operator can recheck the positioning and orientation of
the nozzle by removing the plug and reinserting the laser.

[0034] The method includes aligning the laser beam
along a line which passes through the stream reference
point and the machining reference point as described
herein above. This permits the flow nozzle to be posi-
tioned and oriented such that the profile of the coolant
stream matches or is registered with the profile of the
machining interface.

[0035] In an alternative embodiment the nozzle can
provide a separate laser bore that does not interface or
communicate with the fluid passage of the nozzle. In this
embodiment the laser bore will penetrate a rear portion
of the nozzle and pass complete through a front portion
of the nozzle, typically immediately adjacent the outlet
opening in the nozzle. The emitted visual beam from the
laser inserted into the laser bore passes through the out-
let opening of the laser bore and is directed towards the
metalworking machine. The angle of the laser beam em-
itted can be parallel with the angle of the stream of coolant
fluid emitted from the nozzle.

[0036] In the above embodiment, the discharge or the
outlet opening of the laser orifice can be covered with a
clear glass material which permits the laser beam to pass
there through, but which prevents coolant fluid from
splashing back into the opening of the laser bore.

[0037] The present invention is carried into practice
using a multi-axis milling machine adapted to operate
using a grinding wheel in place of the normal milling cut-
ter. A main reason for using a multi-axis machine of this
kind is its ability to reproduce complex surface profiles
on the ground workpiece, although this particular topic
is outside the scope of the present invention. It is to be
understood, therefore, that the relative motions of the
grinding wheel and workpiece can be compound move-
ments, notwithstanding that for simplicity the accompa-
nying drawing represents such relative movement as rec-
tilinear.

Claims

1. A metal machining apparatus for removal of metal
from a workpiece (6), comprising:

1) a holder for a workpiece,
2) a metalworking tool (2) that is configured to
engage the workpiece (6) along a machining in-
terface (19) to remove metal from the workpiece;
3) a coolant nozzle (20) for emitting a stream
(18) of a coolant fluid, the nozzle comprising a
bore (22), wherein the flow passage has
an inlet (28) and an outlet (29), and the laser
bore (22) has a line of sight with the flow passage
outlet (29), and
characterised by
4) a visible laser (40) removably inserted into
the laser bore (22), which cooperates with the
nozzle body (21) for visually positioning the noz-
kle relative to the metalworking tool (2), whereby
the emitted stream (18) of coolant fluid can be
directed at the machining interface (19).

2. The metal machining apparatus according to Claim
1 wherein the machining interface (19) comprises a
machining reference point (15), and the flow pas-
sage outlet (29) has a stream reference point (25),
whereby the coolant nozzle (20) can be positioned
by aligning a visible laser beam that is emitted from
the laser along a line (23) passing through the stream
reference point (25) and the machining reference
point (15).

3. The metal machining apparatus according to Claim
1 wherein coolant nozzle (20) is configured for re-
moval of the visible laser (40), and for insertion of a
removable plug (50) into the laser bore (22).

4. The metal machining apparatus according to Claim
3 wherein the removable plug (50) has a distal end
(52) having a surface (56), wherein the surface mimics the shape of the inner surface of the flow passage (27) that had been removed when the laser bore (22) was formed in the nozzle body (21).

5. A laser-targeted coolant nozzle (20) for use in applying coolant fluid to a machining apparatus (2) for removal of metal from a workpiece (6) at a machining interface (19), comprising:

1) a coolant nozzle body (21) having a flow passage (27) and a laser bore (22), wherein the flow passage has an inlet (28) and an outlet (29), and the laser bore (22) forms an access opening (24) in the outer surface of the nozzle body (21) and has a line of sight with the flow passage outlet (29), and

characterised by

2) a visible laser (40) removably inserted into the laser bore (22), which cooperates with the nozzle body (21) for visually positioning the coolant nozzle (20) relative to the machining apparatus, whereby the stream (18) of coolant fluid can be directed at the machining interface (19).

6. The laser-targeted coolant nozzle (20) according to Claim 5 wherein the laser bore (22) is in fluid communication with the flow passage (27).

7. The laser-targeted coolant nozzle (20) according to Claim 5 wherein the coolant nozzle is further provided with a removable plug (50) that can be inserted into the laser bore (22) in place of the laser, to seal the access opening (24) from fluid communication with the flow passage (27).

Patentansprüche

1. Metallbearbeitungsvorrichtung zum Entfernen von Metall von einem Werkstück (6), aufweisend:

1) einen Halter für ein Werkstück,
2) ein Metallbearbeitungswerkzeug (2), das so eingerichtet ist, dass es an dem Werkstück (6) entlang einer Bearbeitungsstelle (19) angreift, um Metall von dem Werkstück zu entfernen;
3) eine Kühlmitteldüse (20) zum Ausgeben eines Strömungskanals (27) und einer Laserbohrung (22) aufweist, in welcher der Strömungskanal einen Einlass (28) und einen Auslass (29) hat, und die Laserbohrung (22) eine Sichtlinie mit dem Strömungskanalaußendurch: 4) einen herausnehmbaren Stopfen (50) mit einer Oberfläche (56), die gibt, und gekennzeichnet durch:

1) einen Kühlmitteldüsenkörper (21) mit einem Strömungskanal (27) und einer Laserbohrung (22), wobei der Strömungskanal einen Einlass (28) und einen Auslass (29) hat, und die Laserbohrung (22) eine Zugangsoffnung (24) in der Außenoberfläche des Düsenkörpers (21) bildet und eine Sichtlinie mit dem Strömungskanalaußendurch:

2) einen herausnehmbaren Stopfen (50) mit einer Oberfläche (56), wobei die Düsene den Düsenkörper (21) mit einem Strömungskanal (27) und einer Laserbohrung (22) aufweist, in welcher der Strömungskanal einen Einlass (28) und einen Auslass (29) hat, und die Laserbohrung (22) eine Sichtlinie mit dem Strömungskanalaußendurch:

3) eine Kühlmitteldüse (20) mit Laserzieleinrichtung zur Verwendung bei der Aufbringung von Kühlmittelfluid auf eine Bearbeitungsmaschine (2) zum Entfernen von Metall von einem Werkstück (6) an einer Bearbeitungsstelle (19), aufweisend:

1) einen Kühlmitteldüsenkörper (21) mit einem Strömungskanal (27) und einer Laserbohrung (22), wobei der Strömungskanal einen Einlass (28) und einen Auslass (29) hat, und die Laserbohrung (22) eine Zugangsoffnung (24) in der Außenoberfläche des Düsenkörpers (21) bildet und eine Sichtlinie mit dem Strömungskanalaußendurch:

4) einen herausnehmbaren Stopfen (50) mit einer Oberfläche (56), wobei die Düsene den Düsenkörper (21) mit einem Strömungskanal (27) und einer Laserbohrung (22) aufweist, in welcher der Strömungskanal einen Einlass (28) und einen Auslass (29) hat, und die Laserbohrung (22) eine Sichtlinie mit dem Strömungskanalaußendurch:
7. Kühlmitteldüse (20) mit Laserzieleinrichtung nach Anspruch 5, wobei die Kühlmitteldüse ferner mit einem herausnehmbaren Stopfen (50) versehen ist, der in die Laserbohrung (22) anstelle des Lasers eingesetzt werden kann, um die Zugangsoffnung (24) gegen eine Fluidverbindung mit dem Strömungskanal (27) abzudichten.

Revendications

1. Appareil d’usinage de métal pour le retrait du métal d’une pièce à travailler (6), comprenant :
   1) un support pour une pièce à travailler,
   2) un outil (2) pour le travail des métaux étant configuré pour engager la pièce à travailler (6) le long d’une interface (19) d’usinage pour retirer le métal de la pièce à travailler ;
   3) une buse (20) de refroidissement pour émettre un flux (18) de fluide de refroidissement, la buse comprenant un corps (21) de buse présentant un passage (27) d’écoulement et un alésage (22) laser, dans lequel le passage d’écoulement présente une entrée (28) et une sortie (29), et l’alésage (22) laser possède une ligne de visée avec la sortie (29) de passage d’écoulement, et caractérisé en ce que :
   4) un laser visible (40) inséré de manière amovible dans l’alésage (22) laser, qui coopère avec le corps (21) de buse pour positionner visuellement la buse par rapport à l’outil (2) pour le travail des métaux, de sorte que le flux (18) de fluide de refroidissement puisse être dirigé en direction de l’interface (19) d’usinage.

2. Appareil d’usinage de métal selon la revendication 1 dans lequel l’interface (19) d’usinage comprend un point (15) de repère d’usinage, et la sortie (29) de passage d’écoulement présente un point (25) de repère de flux, de sorte que la buse (20) de refroidissement puisse être positionnée en alignant un faisceau laser visible qui est émis à partir du laser le long d’une ligne (23) traversant le point (25) de repère de flux et le point (15) de repère d’usinage.

3. Appareil d’usinage de métal selon la revendication 1 dans lequel la buse (20) de refroidissement est configurée pour le retrait du laser visible (40), et pour l’insertion d’une fiche amovible (50) dans l’alésage (22) laser.

4. Appareil d’usinage de métal selon la revendication 3 dans lequel la fiche amovible (50) présente une extrémité distale (52) possédant une surface (56), dans lequel la surface imite la forme de la surface intérieure du passage (27) d’écoulement qui avait été supprimée lorsque l’alésage (22) laser avait été formé dans le corps (21) de buse.

5. Buse (20) de refroidissement ciblée au laser pour être utilisée pour l’application d’un fluide de refroidissement pour un appareil (2) d’usinage pour le retrait du métal d’une pièce à travailler (6) au niveau d’une interface (19) d’usinage, comprenant :
   1) un corps (21) de buse de refroidissement présentant un passage (27) d’écoulement et un alésage (22) laser, dans lequel le passage d’écoulement présente une entrée (28) et une sortie (29), et l’alésage (22) laser forme une ouverture (24) d’accès dans la surface extérieure du corps (21) de buse et présente une ligne de visée avec la sortie (29) de passage d’écoulement, et caractérisé en ce que :
   2) un laser visible (40) inséré de manière amovible dans l’alésage (22) laser, qui coopère avec le corps (21) de buse pour positionner visuellement la buse (20) de refroidissement par rapport à l’appareil d’usinage, de sorte que le flux (18) de fluide de refroidissement puisse être dirigé en direction de l’interface (19) d’usinage.

6. Buse (20) de refroidissement ciblée au laser selon la revendication 5 dans laquelle l’alésage (22) laser est en communication de fluide avec le passage (27) d’écoulement.

7. Buse (20) de refroidissement ciblée au laser selon la revendication 5 dans laquelle la buse de refroidissement est en outre munie d’une fiche amovible (50) pouvant être insérée dans l’alésage (22) laser à la place du laser, pour rendre étanche l’ouverture (24) d’accès de la communication de fluide avec le passage (27) d’écoulement.