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(72) **Inventor; and**
(71) **Applicant** : **KRAUTER, David** [US/US]; 2403 East Aloha Street, Seattle, WA 98112 (US).

(74) **Agent**: **ROGGE, Dwayne**; Hughes Law Firm, PLLC., 5160 Industrial Place, Suite 107, Ferndale, WA 98248 (US).

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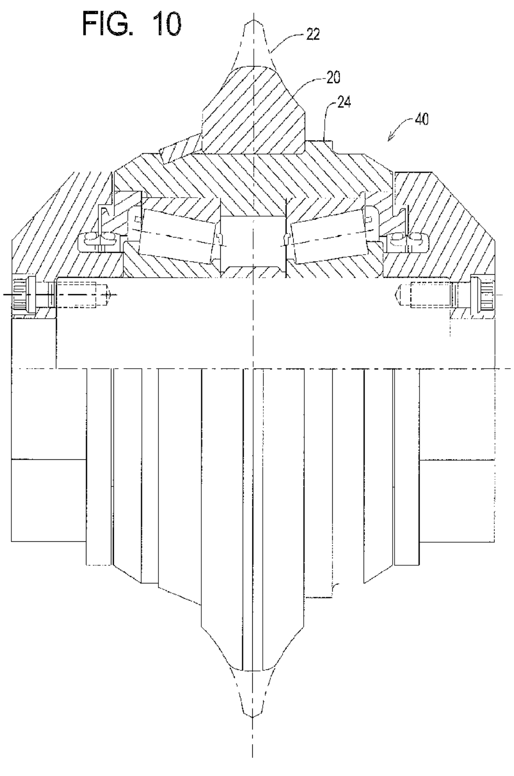
(54) **Title**: CUTTER RINGS AND METHOD OF MANUFACTURE

FIG. 10




(57) **Abstract**: Disclosed herein is a ring cutter for a tunneling apparatus, the ring cutter formed by a process in one form comprising several steps. In one form, this mold is sacrificial, and may be a pair of parallel cylinders such as an outer and an inner cylinder with a gap there between. In one manufacturing process, a single mold is used to produce multiple cutters which are cast simultaneously within the single mold. In one form, the mold is formed in the final shape of the cutter, such that the cutter requires no further machining to be used in a tunneling apparatus. Another step being: disposing a volume of powdered metal, such as a nickel based alloy, into the mold. The powdered metal may then be subjected to isostatic gas pressures, and elevated sintering temperatures simultaneously (HIP) with the isostatic gas pressure to consolidate the powdered metal.

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

# CUTTER RINGS AND METHOD OF MANUFACTURE

## RELATED APPLICATIONS

This application claims priority benefit of U.S. Serial Number 61/372,208, filed 08/10/2010.

## BACKGROUND OF THE DISCLOSURE

a) Field of the Disclosure

The present invention pertains to a roller cutter assembly for rock boring machines. Rock boring machines have a plurality of these cutter assemblies mounted on a rotatable cutterhead. Conventionally, each cutter assembly includes a shaft which is adapted to be secured to the cutterhead, a hub mounted on bearings for rotation relative to the shaft and the cutterhead, and a cutter ring being fixedly secured to the hub. The rock breaking elements on the cutter ring can be a so-called disc cutter with a peripheral cutting edge. These cutter element arrangements are generically termed “cutter rings”.

Furthermore, this disclosure relates to an improved cutting surface used in the field of cutting, severing or breaking up of naturally occurring solid, hard Earth (ground) material. Such cutting, severing or breaking up of solid, hard material generally comprises forming an opening or cut in native material of larger cross-sectional surface area than the effective cutting area of the cutting means by movement of the means parallel to the exposed surface, and forming a large passageway into the earth by continuously advancing a cutting device by means of a vehicle or the like, the cutting means forming the entire passageway in an uninterrupted advance movement as the vehicle or the like follows the cutting means into and along the passageway. In this disclosure, the cutter rings are formed in a process of hot isostatic pressing of powder metal.

## SUMMARY OF THE DISCLOSURE

Disclosed herein is a ring cutter for a tunneling apparatus, the ring cutter formed by a process in one form comprising several steps. One step of the process being the step of providing a mold of the cutter, the mold may be cylindrical, or may be more in the shape of the final cutter. In one form, this mold is sacrificial, and may be a pair of parallel cylinders such as an outer and an inner cylinder with a gap there between. In one manufacturing process, a single mold is used to produce multiple cutters which are cast simultaneously within the single mold. In one form, the mold is formed in the final shape of the cutter, such that the cutter tip requires no further machining to be used in a tunneling apparatus. Another step being: disposing a volume of powdered metal, such as a nickel based alloy, into the mold. The powdered metal may then be subjected to isostatic gas pressures, and elevated sintering temperatures simultaneously (HIP) with the isostatic gas pressure to consolidate the powdered metal. In this step, the pressures used may be up to 7,350 PSI, 15,000 PSI, 45,000 PSI, or more in some applications. Argon gas may be used in the HIP process. The temperatures may exceed 900ºF or even 2,400ºF. In one form the elevated temperatures are sufficient to sinter the powdered metal. One additional step being to subject the consolidated powdered metal to an austenitization process. The temperatures used in the austenitization process may exceed 1650º F.

Also disclosed is a method of fabricating a cutter ring for a tunneling device, the method comprising several steps. One step may be: securing an mold about the circumference of an inner ring so as to create a cavity defined by the mold and a surface of the inner ring. This step followed by a step of filling the cavity with an alloy, which is in powder form, to form a cutter ring assembly; then sealing the cavity; then heating the cutter ring assembly to a selected temperature while applying pressure as a HIP process.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a highly schematic cross-sectional view of one portion of one embodiment of an improved cutter ring.

Fig. 2 is a highly schematic cross-sectional view of one embodiment of a step in production of a plurality of improved cutter rings as shown in Fig. 1.

Fig. 3 is a highly schematic cross-sectional view of one portion of one variation of an improved cutter ring, as shown in Fig. 1.

Fig. 4 is a highly schematic cross-sectional view of one portion of another variation of an improved cutter ring, as shown in Fig. 1.

Fig. 5 is a highly schematic cross-sectional view of one portion of another embodiment of an improved cutter ring.

Fig. 6 is a highly schematic cross-sectional view of one embodiment of a step in production of a plurality of improved cutter rings, as shown in Fig. 5.

Fig. 7 is a highly schematic cross-sectional view of one portion of one variation of an improved cutter ring, as shown in Fig. 5.

Fig. 8 is a highly schematic cross-sectional view of one portion of another variation of an improved cutter ring, as shown in Fig. 5.

Fig. 9 is a cutaway view of one embodiment of an improved cutter ring mounted to an additional structure.

Fig. 10 is a view of a worn cutter ring and associated structures.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Disclosed herein is an improved cutter ring for tunneling devices, such as the cutter rings disclosed, for example, in US 3,787,101 and 7,401,537, incorporated herein by reference, the understanding of which will allow one of ordinary skill in the art to readily understand the application and benefits of the disclosed cutter rings and methods of manufacture thereof. Such tunneling devices are well known in the art for mining, tunneling for subway trains, and similar applications. These ring cutters differ in function and application from both drag bits, and tri-cone boring bits attached to a down hole shaft. As the cutter rings directly engage the surface of hard rock for cutting and tunneling therethrough, the cutter rings wear out and require replacement. This is obviously detrimental to the operation of the device as tunneling cannot occur during the replacement process. As is shown in US 3,787,101, these cutter assemblies are removably attached to the drilling machine through a mounting portion well described in this patent. Additionally, the assembly is comprised of a replaceable outer portion, described herein as the cutter ring itself, and a larger hub assembly.

Looking to Fig. 9 of this disclosure, a cutter ring 20 is shown having a cutting edge 22, which rolls over the rock face during operation (tunneling). As shown, the cutter ring 20 is fixedly and removably attached to a hub 24 in one form by way of an interference fit with adjoining surfaces 26. In one form, a first lip 28 prohibits movement of the cutter ring 20 relative to the hub 24 in a first longitudinal direction 30, while a second lip 32 prohibits movement of the cutter ring 20 relative to the hub 24 in a second longitudinal direction 34. As shown, the hub 24 is mounted through a plurality of bearings 36 to a housing 38. The housing 38 is rigidly fixed to or formed as part of a larger structure which interconnects a plurality of cutting assemblies 40, on a cutter head. This is only one example of a cutter ring assembly utilizing the disclosed improvements.

Looking to Fig. 10, of cutting assembly 40, generally comprising a cutter ring 20 and hub assemblies 24, is shown. It can be seen in this figure that the cutting edge 22 of the replaced cutting assemblies is well worn from the original shape shown by the dashed line, and requires sharpening or replacement before being replaced into the larger structure for tunneling or drilling.

Traditionally these cutter rings are formed by forging, casting, or machining. This disclosure describes several cutter rings formed using a powder metal process utilizing hot isostatic pressure sintering of the powder metal. Powder metallurgy is a forming and fabrication technique consisting of three major processing stages. First, the primary material is physically powdered, divided into many small individual particles. Next, the powder is injected into a mold wherein the end part is formed by applying pressure, high temperature, long setting times (during which self-welding occurs), or any combination thereof.

Hot isostatic pressing (HIP) is a manufacturing process used to reduce the porosity of metals and influence the density of many ceramic materials. This improves the material's mechanical properties and workability.

The HIP process subjects a component to both elevated temperature and isostatic gas pressure in a high-pressure containment vessel. The pressurizing gas most widely used is argon, although other gasses may be used. An inert gas is used so that the material does not chemically react with the gas. The chamber and metal therein is heated, causing the pressure inside the vessel to increase. Many systems use associated gas pumping to achieve the necessary pressure level. Pressure is applied to the material from all directions (hence the term "isostatic").

For processing castings, the inert gas is applied between 7,350 psi (50.7 MPa) and 45,000 psi (310 MPa), with 15,000 psi (100 MPa) being most common. Process soak temperatures range from 900 °F (482 °C) for aluminum castings to

2,400 °F (1,320 °C) for nickel-based superalloys. When castings are treated with HIP, the simultaneous application of heat and pressure eliminates internal voids and microporosity through a combination of plastic deformation, creep, and diffusion bonding. Primary applications are the reduction of microshrinkage, the consolidation of powder metals, ceramic composites and metal cladding. Hot isostatic pressing is also used as part of a sintering (powder metallurgy) process and for fabrication of metal matrix composites.

Disclosed herein is an improved method for making an improved cutter ring 20, which is more wear resistant than any known cutter rings. Two embodiments will be utilized to describe this process, with multiple variations of both embodiments.

The first embodiment is shown in Fig. 1, with variations shown at Figs. 3 and 4. Fig. 2 generally shows one method for simultaneously producing several cutter rings of this first embodiment.

The second embodiment is shown in Fig. 5, with variations shown at Figs. 7 and eight. Fig. 6 generally shows one method for producing this second embodiment.

A process to simultaneously manufacture several copies of the cutter ring of the first embodiment 42 is perhaps most easily understood by looking to Fig. 2. As shown, a plurality of first embodiment cutter rings 44 (a-h) are simultaneously produced in a canister, around an inner tube 46. An inner tube 46 is provided, whereupon a thin canister (mold) 48 is then attached at either (or both) end (50a or 50 b) to the inner tube 46, whereupon a volume of powder metal 52 is disposed in the gap 54 between the canister 48 and the inner tube 46. Where upon, this assembly is subjected to hot isostatic pressing as described above. The powder metal then consolidates and securely bonds to the wrought inner tube 46 during the HIP process. Once complete, the assembly 56 is cut along lines 58 to form unique cutter rings 44. Additionally, the assembly 56 is machined following the HIP/sintering step and/or forged to form the outer surface 58 of the individual cutter rings 44.

In the first variation 60 shown in Fig. 3, a different method of manufacture is disclosed wherein a formed outer cover (mold) 62 is welded or otherwise attached to the machined inner ring 66. In one form, the outer cover 62 is formed of sheet metal or an equivalent. A volume of powder metal 64 forming a core is then disposed into the void formed between the outer cover 62 and the upper surface of the inner ring 66. This assembly 76 is then subjected to an HIP process, such as described above, bonding the powder metal into a unitary structure which is also chemically and mechanically bonded to the inner ring 66 forming a unitary cutter ring which will require minimal machining on the bore to achieve a final product. The outer cover 62 will quickly be worn away in use, or may be removed prior to installation of the cutter ring 20 upon a hub 24. The production process may be completed by submitting the assembly 76 to an austenitization process. In one form, the temperatures used in the austenitization process exceed 1650º F.

By changing the temperature for austenitization, the austempering process can yield different and desired microstructures. A higher austenitization temperature can produce a higher carbon content in austenite, whereas a lower temperature produces a more uniform distribution of austempered structure. The carbon content in austenite as a function of austempering time has been established

In the second variation 68 shown in Fig. 4, yet another method of manufacture is disclosed wherein a cover 70 is welded or otherwise attached to the inner ring 74 and substantially encompasses the inner ring 74 and an open region defined by the cover 70 and the radially outward surface of the ring 74. Once again, a volume of powder metal 72 is disposed within an open region . As with previous embodiments, the assembly 78 is then subjected to an HIP process, such as described above, to form a cutter ring. Again, the outer cover

70 may quickly be worn away in use, or may be removed prior to installation of the cutter ring 20 upon a hub 24. This process also may be completed by submitting the assembly 76 to an austenitation process. In one form, the temperatures used in the austenitization process exceed 1650º F. As with the first variation, this assembly also may not require additional machining between the HIP/sintering step and installation.

In the second embodiment 80, shown in Figs. 5-8, the entire cutter ring 82 is formed of a solid and unitary powder metal structure.

In one form of production as shown in Fig. 6, the cutter rings 82 are formed by providing a longitudinally oriented tubular canister 84, having an inner surface 86, an outer surface 88 and end surfaces 90A, 90B. A volume of powder metal 92 is disposed within the tubular canister and subjected to an HIP process, such as described above, forming a long tube of powder metal material from which individual cutter rings 82a-82h are cut and machined. Again, the outer cover will quickly be worn away in use, or may be removed prior to installation of the cutter ring upon a hub. The process may be completed by submitting each ring 82 to an austenitation process. In one form, the temperatures used in the austenitization process exceed 1650º F.

In the first variation 90 of the second embodiment, shown in Fig. 7, a formed canister (mold) 92 is formed as a ring having the cross sectional shape, the upper portion of which is generally as shown in Fig. 7. Into this canister is deposited a volume of powder metal 94. The entire assembly 96 is then subjected to the HIP process, such as that disclosed above, whereupon a unitary, singular cutter ring 90 is formed. In one form, the canister 92 is formed of sheet metal. As with the previous embodiments, the outer cover will quickly be worn away in use, or may be removed prior to installation of the cutter ring upon a hub 24. The process may be completed by submitting the assembly 76 to an austenitation process. In one form, the temperatures used in the austenitization process exceed 1650º F.

Alternatively, a second variation 98 of the second embodiment 80, shown in Fig. 8, is disclosed. This second variation 98 is formed by providing a formed sheet metal canister 100, which is substantially rectangular in cross section. Into this canister 100 is deposited a volume of powder metal 102. This assembly 104 is then subjected to the HIP process, such as that described above. The resulting assembly 104 is then machined or forged to the contour generally shown at 106, resulting in a unitary structure, singular cutter ring. The outer cover is removed prior to or during machining of the ring to the final cutter shape. The process is then completed by submitting the machined ring to an austenitation process. In one form, the temperatures used in the austenitization process exceed 1650º F.

The term sacrifice used herein is defined as the surrender or destruction of something prized or desirable for the sake of something considered as having a higher or more pressing value. In this case, the mold, or a portion thereof, may be sacrificed to more easily produce a very hard cutter ring with potentially less expense than with a non-sacrificial mold..

While the present invention is illustrated by description of several embodiments and while the illustrative embodiments are described in detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications within the scope of the appended claims will readily appear to those sufficed in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicants' general concept.

## THEREFORE I CLAIM

1. A ring cutter for a ground boring apparatus, the cutter ring formed by a process comprising the steps of:
    a. providing a mold of the cutter;
    b. disposing a volume of powdered metal into the mold;
    c. subjecting the powdered metal to isostatic gas pressures;
    d. subjecting the powdered metal to elevated sintering temperatures simultaneously with the isostatic gas pressure to consolidate the powdered metal; and
    e. wherein the elevated temperatures are sufficient to sinter the powdered metal.
2. The process as recited in claim 1 wherein the mold is sacrificial.
3. The process as recited in claim 1 wherein the temperatures used in the austenitization process exceed 1650º F.
4. The process as recited in claim 1 further comprising the step of metal injection molding.
5. The process as recited in claim 1 wherein Argon gas is used in the step of subjecting the powdered metal to isostatic gas pressures.
6. The process as recited in claim 1 wherein the elevated sintering temperatures exceed 900ºF.
7. The process as recited in claim 6 wherein the elevated sintering temperatures exceed 2,400ºF.
8. The process as recited in claim 7 wherein the powdered metal is a nickel-based alloy.

9. The process as recited in claim 1 wherein the isostatic gas pressures exceed 7,350 PSI.

10. The process as recited in claim 9 wherein the isostatic gas pressures exceed 15,000 PSI.

11. The process as recited in claim 9 wherein the isostatic gas pressures is less than 45,000 PSI.

12. The process as recited in claim 1 wherein the mold is substantially an inner cylinder and an outer cylinder.

13. The process as recited in claim 12 wherein multiple cutters are cast simultaneously within a single mold.

14. The process as recited in claim 1 wherein the cutter requires no further machining to be used in a tunneling apparatus.

15. A method of fabricating a cutter ring for a tunneling device, the method comprising the steps of:

   a. securing an mold about the circumference of an inner ring so as to create a cavity defined by the mold and a surface of the inner ring;

   b. filling the cavity with an alloy, which is in powder form, to form a cutter ring assembly;

   c. sealing the cavity;

   d. heating the cutter ring assembly to a selected temperature;

   e. placing the heated cutter ring assembly in a hot isostatic press while the cutter ring assembly is heated to the selected temperature; and

   f. subjecting the cutter ring assembly to a predetermined temperature and pressure in the hot isostatic press.

FIG. 1

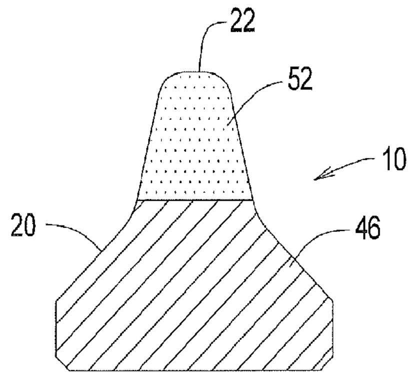

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FIG. 2

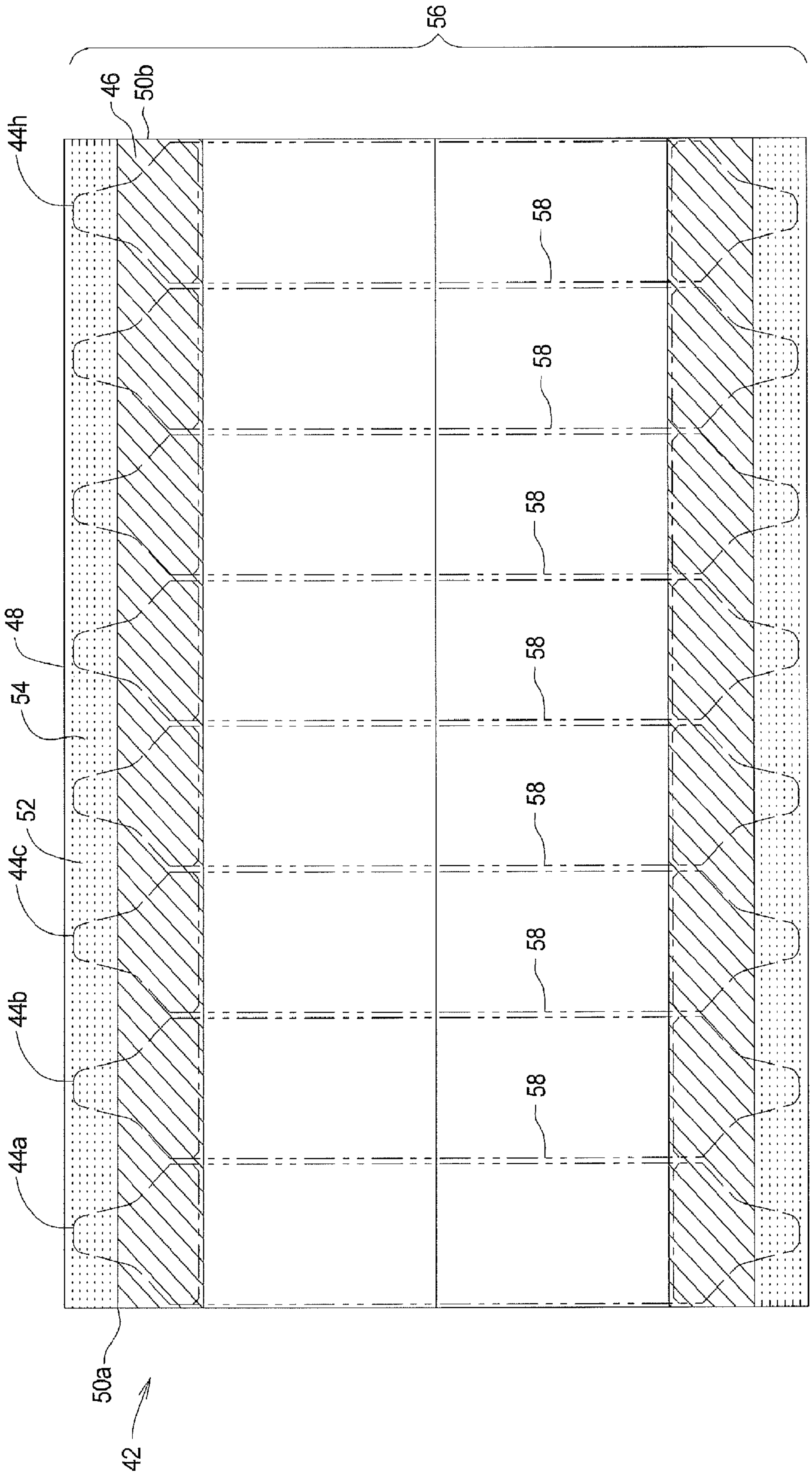


FIG. 3

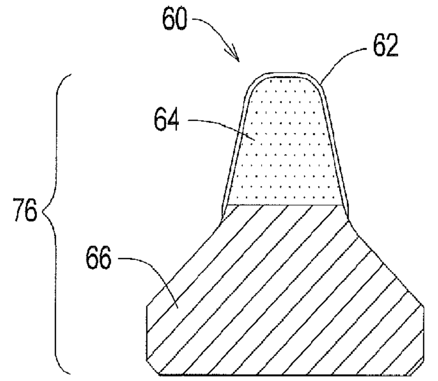



FIG. 4

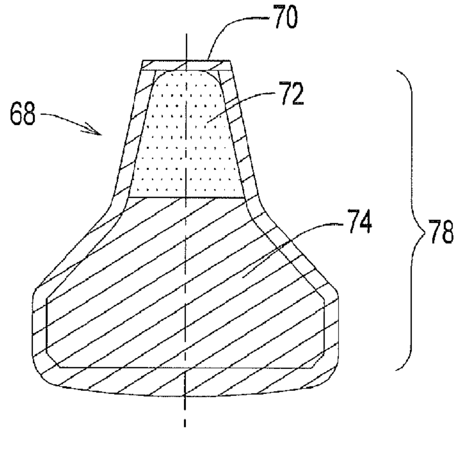



FIG. 5

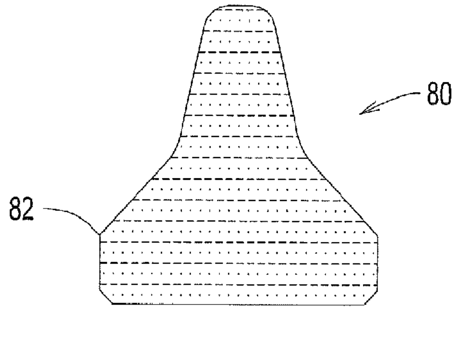


FIG. 6

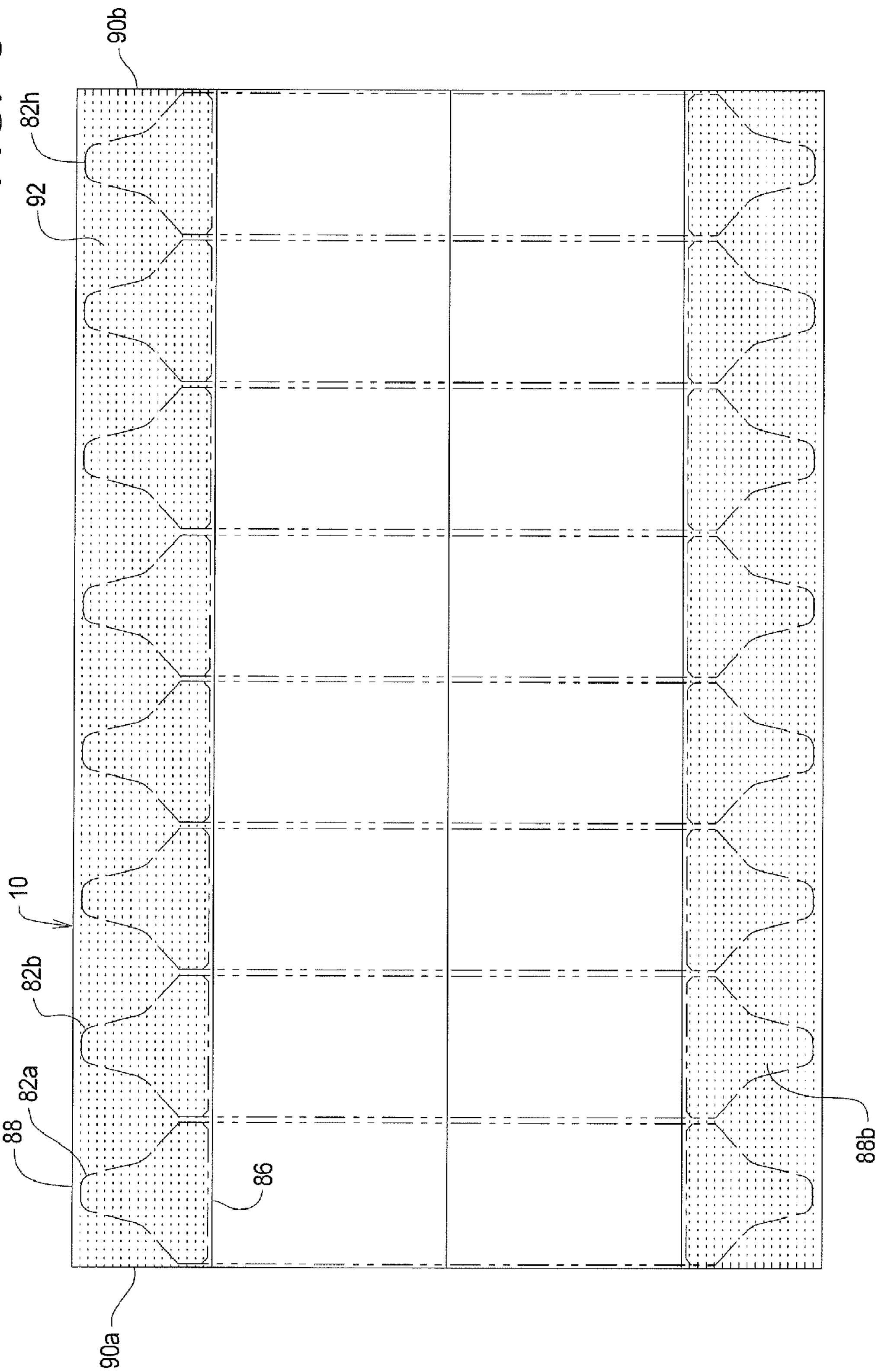


FIG. 7

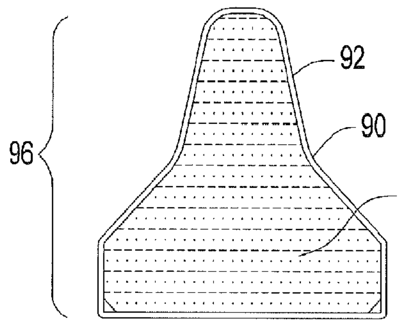



FIG. 8

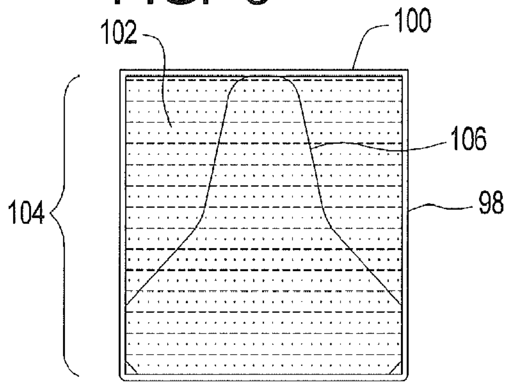



FIG. 9

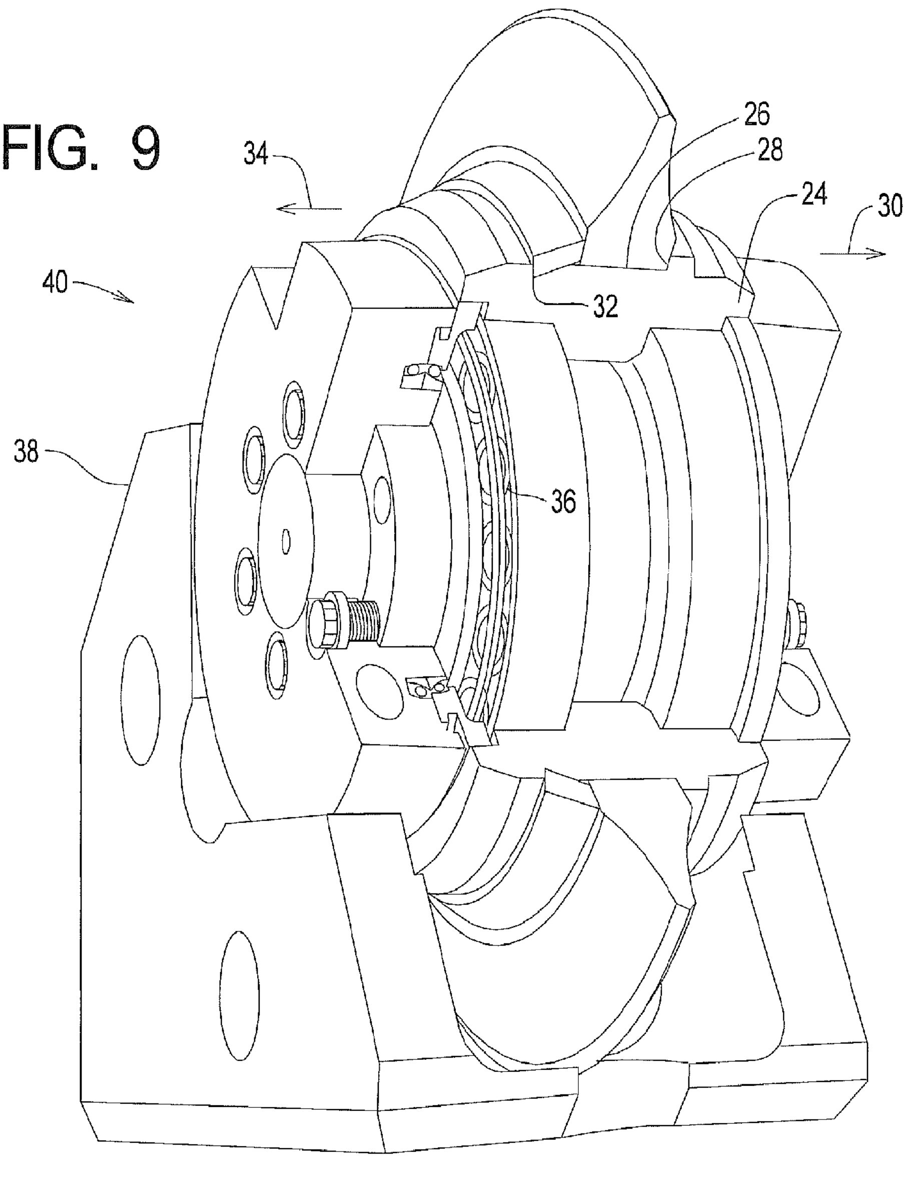
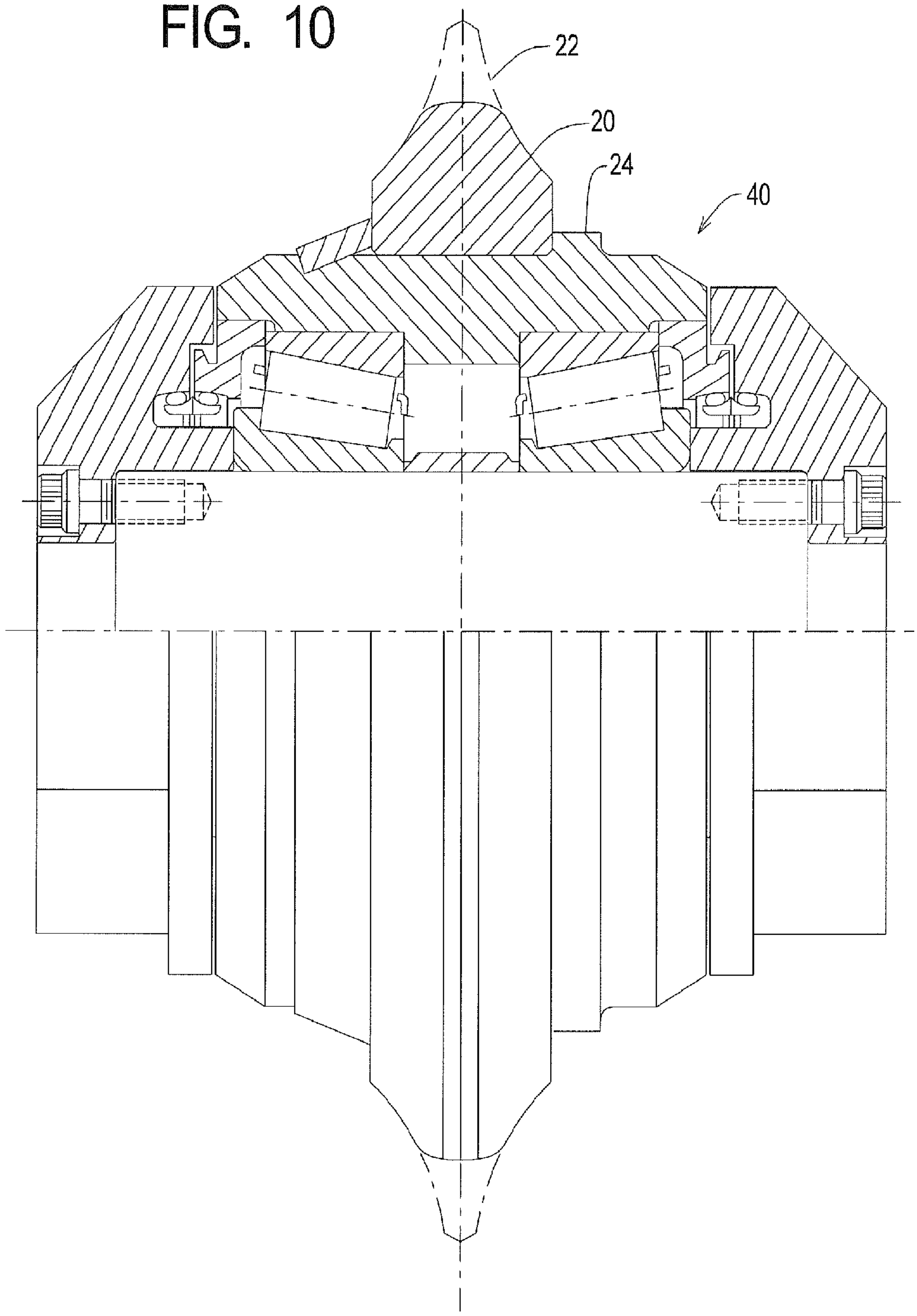


FIG. 10



# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/47233

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC(8) - E21B 10/08 (2011.01)
USPC - 175/324
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)
IPC(8) - E21B 10/08 (2011.01)
USPC - 175/324

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) - E21B 10/08 (2011.01)
USPC - 175/324 (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(USPT,PGPB,EPAB,JPAB); Google Scholar; Google Patents
Search Terms: earth, ground, bore, drill, ring, cut, mold, powdered, sintered, inject, nickel, argon,.. etc.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2007/0251732 A1 (Mirchandani et al.) 01 November 2007 (01.11.2007), para [0012], [0040], [0043] | 1-15 |
| Y | US 2009/0211812 A1 (Puttmann) 27 August 2009 (27.08.2009), fig 7, para [0062] | 1-15 |
| Y | US 5,957,006 A (Smith) 28 September 1999 (28.09.1999), col 7, ln 64-67-col 8, ln 1-4 | 2, 4, 12, 13 |
| Y | US 2009/0274923 A1 (Hall et al.) 05 November 2009 (05.11.2009), para [0072] | 5 |

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 12 January 2012 (12.01.2012) | 24 JAN 2012 |


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