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(71) Applicant (for all designated States except US): **FEDERAL-MOGUL CORPORATION** [US/US]; 26555 Northwestern Highway, Southfield, MI 48034 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **CHRISTOPHER-SON, Denis, Jr.** [US/US]; 812 W. Jefferson Street, Waupun, WI 43963 (US).

(74) Agents: **STEARNS, Robert** et al.; Dickinson Wright PLLC, 38525 Woodward Avenue, Suite 2000, Bloomfield Hills, MI 48304-5092 (US).

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(54) Title: POWDER METAL FRICTION STIR WELDING TOOL

(57) Abstract: A friction stir tool has an axis of rotation and a welding tip that is made of powdered metal material.



WO 2007/109719 A2

POWDER METAL FRICTION STIR WELDING TOOL

BACKGROUND OF THE INVENTION

[0001] This invention claims priority to U.S. Provisional Application Serial No. 60/784,367, filed March 21, 2006.

1. TECHNICAL FIELD

[0002] This invention relates generally to friction stir welding tools, and more particularly to the materials used to make such tools.

2. RELATED ART

[0003] Friction stir welding is a technique whereby the tip of a rotating friction stir tool is first plunged into an unwelded joint of two abutting metal members to be joined, after which the rotating tool is traversed along the joint causing the materials of the two members to be heated sufficiently to reach a plastic state causing displacement or stirring of the plastic materials across the joint interface which, upon cooling, results in a metallurgical weld of the two materials. The technique can also be used to join stacked metal members whereby the rotating tool is plunged through one of the members and part way into the other and then moved along to weld them together.

[0004] Friction stir weld tools are typically wrought and then machined to the desired shape. For example, the tools can be cast from a desired metal alloy and then subjected to machining to impart the desired shape and features to the friction stir tool. The manufacturing and finishing processes can limit the selection of materials available for use as friction stir tooling and further add to the cost and complexity of forming such tooling.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0005] The present invention is directed to a friction stir tool fabricated of powder metal material.

[0006] The invention further contemplates selecting any of a number materials for use in the powder metal manufacture of the friction stir tool. These include metal alloys, blends and add mixtures of the desired constituents or combinations thereof.

[0007] The invention further contemplates the use of high wear, high friction composite materials, such as cermets, and the like to achieve a long lasting but highly effective friction stir tool.

[0008] According to a further particular feature of the invention, the powder metal friction stir tool can be treated to enhance its wear and/or friction characteristics. According to a particular embodiment, the powder metal friction stir tool is iron-based and the active surfaces or a portion of the active surfaces of the friction stir tool are steam treated to induce the formation of Fe_3O_4 , which is a stable form of iron oxide and imparts high wear and enhanced friction characteristics to the working surfaces or portion of the surfaces as desired of the powder metal friction stir tool.

[0009] According to a further particular feature of the invention, it is contemplated that the powder metallurgy process will enable the formation of a gradient structure in either materials and/or properties of the friction stir tool to take advantage of cost and performance benefits that can arise from such a gradient structure. For example, the leading tip or plunger portion of the friction stir tool can be fabricated of a very hard and perhaps more costly powder metal composition, whereas the friction shoulder surfaces of the friction stir tool can be fabricated of a different material which is also wear resistant but may have enhanced friction inducing characteristics to maximize the heating and stirring affect of the tool. Other possibilities include forming the shank of the friction stir tool of one material (perhaps a lower cost material suitable for chucking the tool) while the remaining operating free end of the friction stir tool is made of a different material. Still a further example can include forming the core or center of the friction stir tool of one powder metal composition while the outer portion or sheath of the friction stir tool is made of another material. It will be appreciated at the combinations of materials and their relative arrangements are too numerous to list and that the intent of the present invention is to capture and contemplate the broad concept of using powder metallurgy to achieve a gradient structure in a friction stir tool.

BRIEF DESCRIPTION OF THE DRAWINGS

[00010] These and other advantages and features of the present invention will become more readily appreciated when considered in connection with the following detailed description and drawings, in which:

- [00011] Figure 1 is a schematic perspective view illustrating the principles of friction stir welding;
- [00012] Figure 2 is a schematic plan view illustrating principles of friction welding;
- [00013] Figure 3 is an enlarged fragmentary perspective view of a tip end of a friction stir welding tool;
- [00014] Figure 4 is a further enlarged perspective view of the tip end of a friction weld stir tool; and
- [00015] Figures 5 through 9 are cross-sectional views illustrating different embodiments of friction stir weld tools constructed according to the present invention.

DETAILED DESCRIPTION

[00016] In friction stir welding, a cylindrical, shouldered tool with a profiled probe is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are abutted together. The parts are clamped in a manner that prevents the abutting joining faces from being forced apart as the tool is plunged into and moved along the joint. Frictional heat is generated between the wear resistant welding tool and the material of the work pieces. This heat causes the latter to soften without reaching the melting point and allows traversing of the tool along the joint line. The plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged by the intimate contact of the tool shoulder in the pin profile. This leaves a solid phase bond between the two pieces as the tool passes by. This process can be regarded as a solid phase keyhole welding technique, since a hole to accommodate the probe or tip of the tool is generated, and then filled during the welding sequence.

[00017] Figure 1 illustrates the general principle of friction stir welding employing the friction stir weld tool according to the invention. The friction stir weld tool is generally shown at 10 and may comprise a generally cylindrical shank 12 that enables the tool 10 to be chucked in a rotating tool holder (not shown). The tool 10 includes a working free end 14 which includes a plunger tip or probe 16 which projects centrally from the free end 14 of the tool 10. Spaced from the free end of the probe 16 is a shoulder 18. The face 20 of the shoulder 18 and the outside diameter surface 22 of the probe 16 serves as the functional surfaces in contact with the work pieces 24, 26 to effect the formation of a friction stir weld.

[00018] As mentioned above, the probe 16 is plunged into an abutting joint 28 between the two work pieces 24, 26 while the tool 10 is being rotated. The tool 10 is then advanced along the joint 18 in the direction of arrow A as the tool continues to rotate. The face 20 of the shoulder 18 is pressed down against the upper surfaces of the work pieces 24, 26 on either side of the joint 28 to further work and stir the plasticized metal at the surface to yield a metallurgical weld 30 across the joint 28. Figures 1 and 2 illustrate the construction and operation of the tool in forming the joint 28.

[00019] The friction stir weld tool 10 can take on any of a number of shapes and features. Figures 3 and 4 illustrate one embodiment of the working free end of a tool 10. It can be seen that the probe 16 may be other than cylindrical and provided with flats 32. The present invention is not limited to any particular shape of the tip 16. Figures 3 and 4 further illustrate the shoulder 18 as having a cupped configuration. This may assist in the friction stir welding of the materials, but the invention is not to be limited to any particular shape of the shoulder 18. The overall configuration of the friction weld stir tool is not limited to the disclosed embodiment, which is meant to be exemplary, and contemplates any friction stir tool configuration suitable for friction stir welding that may be presently available or developed in the future.

[00020] Turning now to particular aspects of the present invention, at least the working free end 14 of the friction weld stir tool 10 is fabricated of powder metal which has been compacted and sintered to the desired shape. One advantage of powder metallurgy is that it enables the friction stir tool to be made near net shape to the desired final tool configuration without extensive post fabrication machining or finishing of the tool. Another advantage is that it enables a wide selection of materials that might not otherwise be available for use in connection with wrought friction stir weld tools.

[00021] In one example of Figure 5, the entire friction weld stir tool 10 is fabricated of the same powder metal material. For example, the tool may be fabricated of an iron based pre-alloyed powder metal material, such as M2 or H13 tool steels. These materials are compacted and then sintered to near net shape and may be used with little post-forming finishing of the tools.

[00022] Powder metal material is advantageous in connection with friction stir weld tools in that the inherent porous structure of the material increases the friction coefficient as compared to a wrought material. The use of powder metal also reduces the thermal conductivity as compared to wrought tools. This acts to maintain more heat at the

tool/workpiece interface since the powder metal tool has less of a heat sink effect than that of a wrought tool counterpart. The base material may further be treated or altered to vary the properties, including altering the coefficient of friction and/or the wear resistance. For example, the free end 14 of the tool 10 may be steam treated under high temperature and pressure to effectively oxidize and convert the exposed surface of the tool 10 to Fe_3O_4 , which is a highly stable form of iron oxide, that has the effect of increasing the wear resistance and friction coefficient of the base iron-based powder metal material.

[00023] The invention further contemplates admixing powders with the iron based powder to alter its properties. For example, additions of silica, alumina, ceramic, carbides, and other hard, stable particles such as ferro-molybdenum, ferro-nickel, chromium and/or Tribaloy may be added to increase the wear resistance and friction coefficient of the base powder metal material. The invention is not limited to any particular composition of material and, within its scope, is directed to the broad concept of using powder metallurgy to form friction weld stir tools without regard to any particular composition.

[00024] The use of powder metallurgy also enables the maker of the tool 10 to alter the properties, as desired, in different regions of the tool 10 to provide a gradient structure. This can be achieved by different process treatments to selected regions of the tool whereby altering the composition of the material in different regions. For example, in Figure 6, the probe or tip 16 is made of one material which may have properties of extremely good wear resistance and high hardness in order to best function and withstand the pressures and temperatures associated with the plunging action of the probe 26 as it passes into the material and is then forced through the material under pressure and elevated temperature, whereas the shoulder region 18 may be fabricated of a different material exhibiting good wear resistance but also exhibiting a high friction coefficient to maximize the stirring capabilities of the shoulder during friction stir welding, while still further the shank 12 may be made of yet a different material if desired which may constitute a lower alloy, less expensive material that may exhibit better.

[00025] Figure 7 is a variation on Figure 6 in which the probe 16 and shoulder 18 regions of the tool 10 are fabricated of one powder metal material, whereas the shank 12 is fabricated of a different powder metal composition. Of course, the invention contemplates that the working free end 14 of the tool 10 could be fabricated of powder metal to achieve the advantages described herein which may be cemented or otherwise joined to a tool shank which may not necessarily be made of powder metal in order to reduce costs or

offer an alternative to an all-powder metal friction weld stir tool if desired. This too is contemplated by the present invention.

[00026] Finally, Figure 8 illustrates another gradient powder metal structure of the friction stir weld tool 10, in which the core 34 of the tool 10 may be fabricated of one material, such as a high load, high wear resistance material, in an outer layer or sheath or shell 36, including the shoulder region 18 is fabricated of a different material which may be a wear resistant, but higher coefficient of friction material than that used for the core 34.

[00027] The foregoing invention has been described in accordance with the relevant legal standards, thus the description is exemplary rather than limiting in nature. Variations and modifications to the disclosed embodiment may become apparent to those skilled in the art and do come within the scope of the invention. Accordingly, the scope of legal protection afforded this invention can only be determined by studying the following claims.

We claim:

1. A friction stir welding tool having a welding tip fabricated of powder metal material.
2. The friction stir welding tool of Claim 1 wherein the welding tip includes a plunger nib and a shoulder.
3. The friction stir welding tool of Claim 1 wherein the powder metal material is ferrous-based.
4. The friction stir welding tool of Claim 3 wherein at least a portion of the welding tip contains Fe_3O_4 oxides.
5. The friction stir welding tool of Claim 3 wherein the Ferrous-based powder metal material is add mixed with at least one of alumina, carbide, ferro-molybdenum, ferro-nickel, chrome or Tribaloy.
6. The friction stir welding tool of Claim 1 wherein the powder metal material is cermet.
7. The friction stir welding tool of Claim 1 wherein the powder metal material has gradient properties in which the tip has different properties than that of the shoulder.
8. The friction stir welding tool of Claim 7 wherein the tip has higher wear resistance characteristics than that of the shoulder.
9. The friction stir welding tool of Claim 1 wherein the entire tool is fabricated of powder metal.
10. The friction stir welding tool of Claim 1, wherein the tip and shoulder regions of the tool are fabricated of different materials.

11. The friction stir welding tool of Claim 1 wherein a central core of the tool is fabricated of a different material than that of an outer sheath of the material.

12. The friction stir welding tool of Claim 11 wherein the tip of the tool is made of the core material and the shoulder is made of the sheath material.

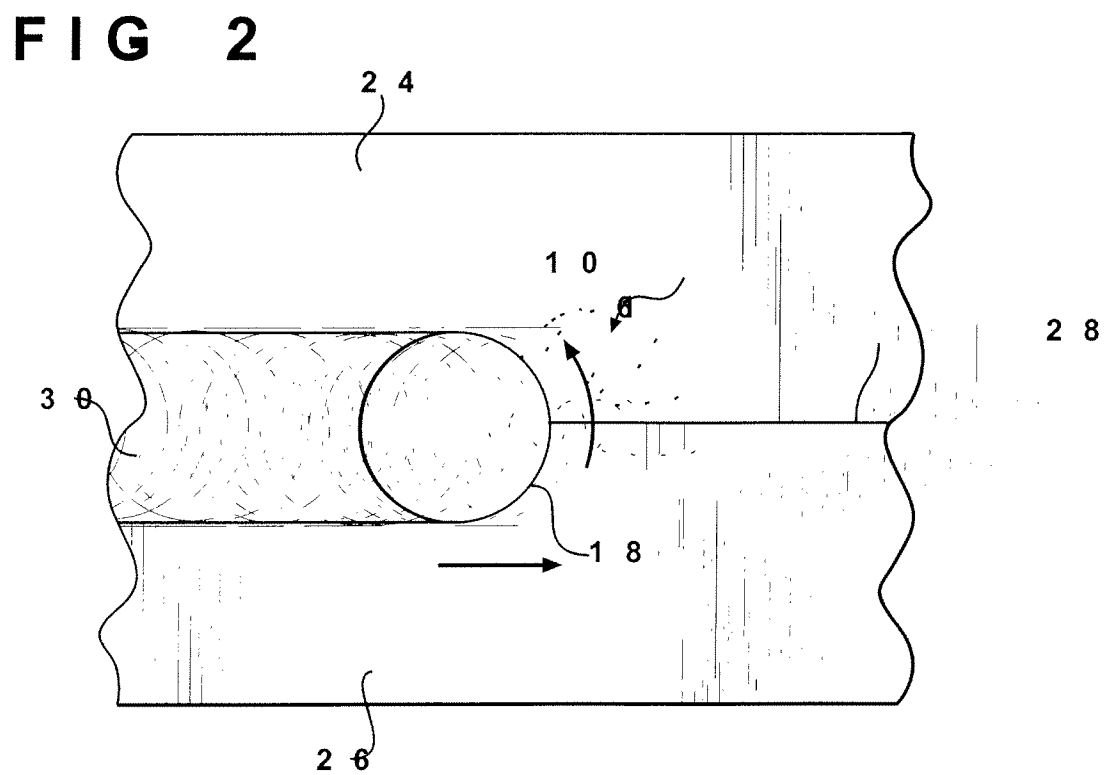
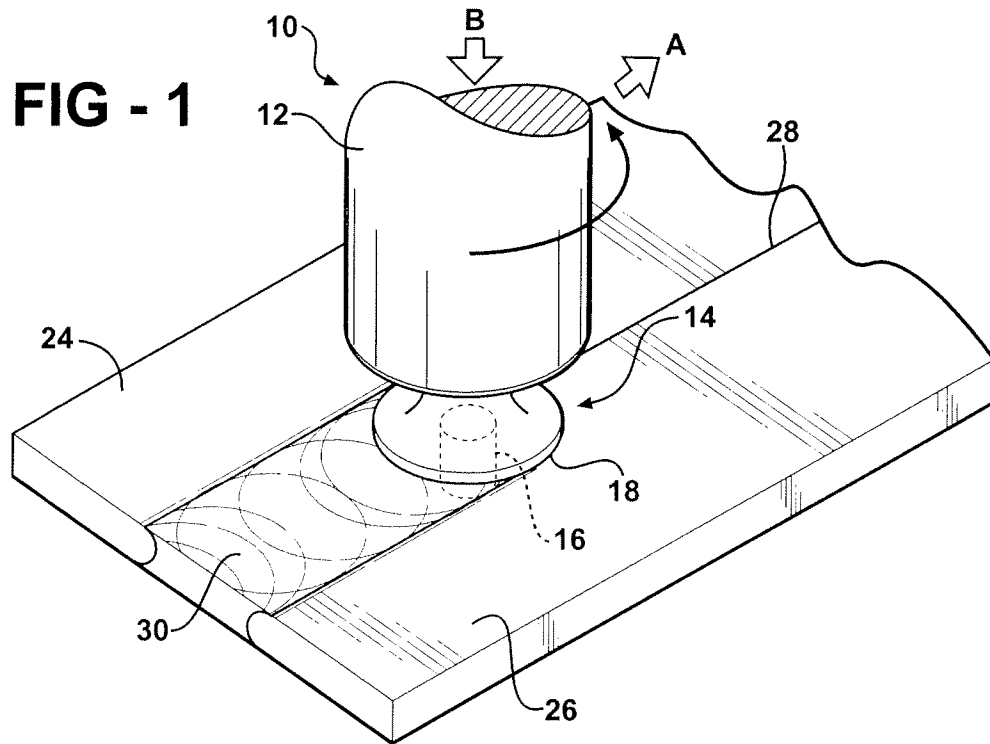


FIG - 3

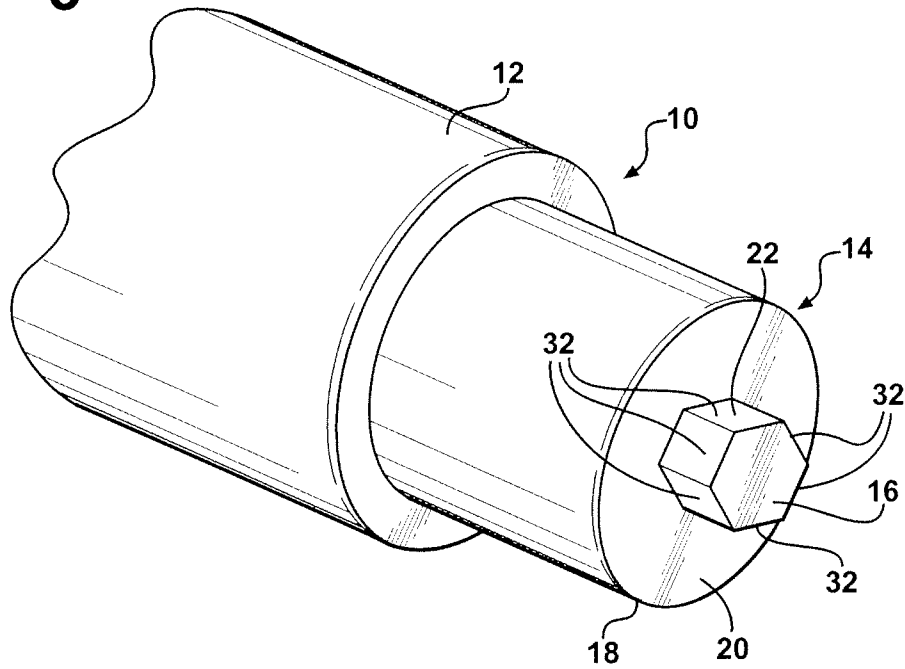


FIG - 4

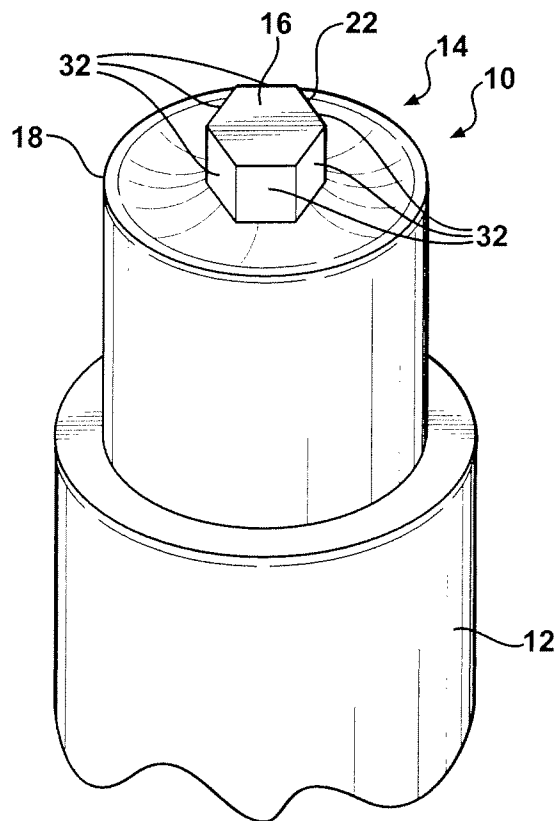


FIG - 5

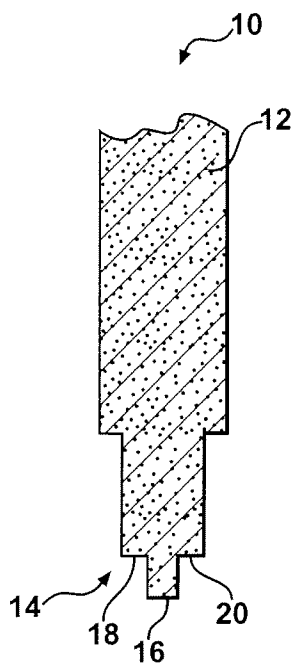


FIG - 6

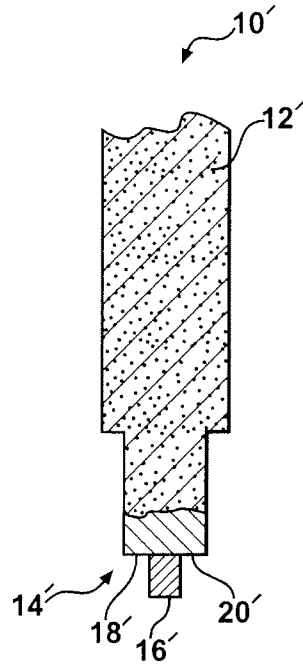


FIG - 7

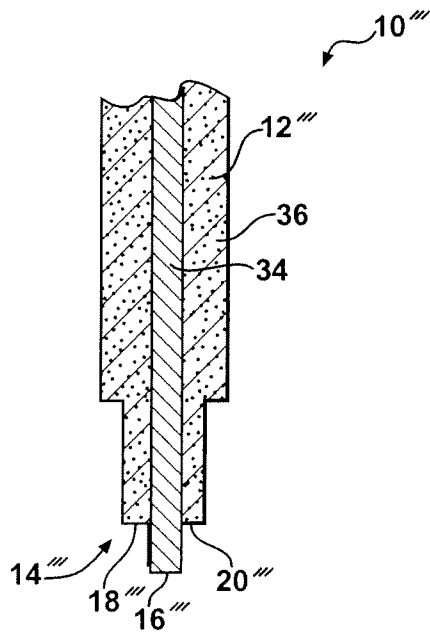
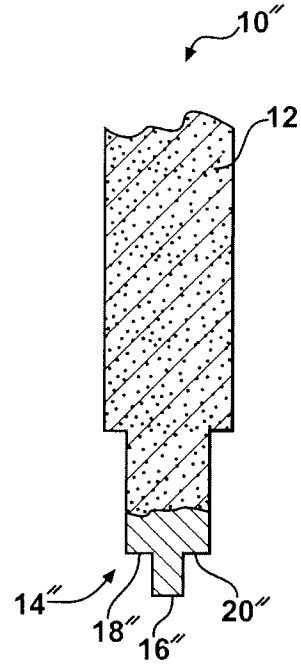


FIG - 8

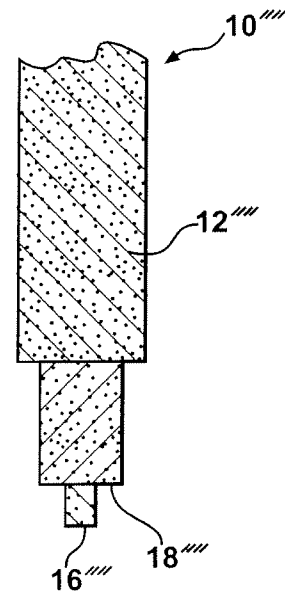


FIG - 9