May 6, 1958 R. G. OWEN 2,833,520

ANNULAR MILL FOR USE IN OIL WELLS

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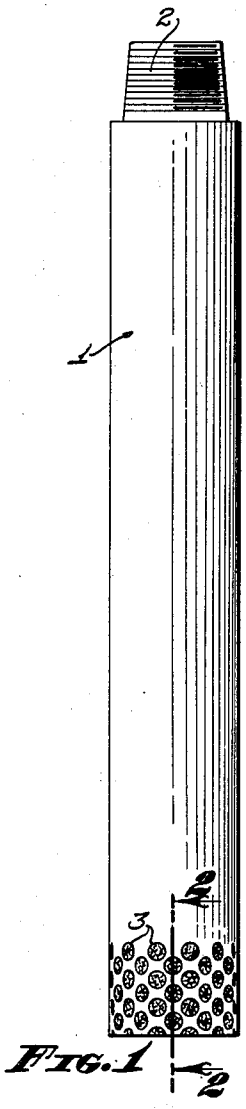


FIG. 1

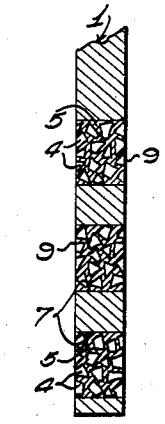


FIG. 2

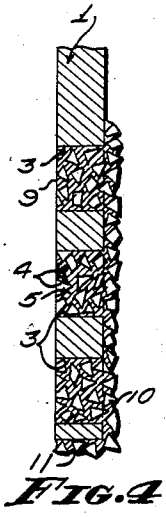


FIG. 4

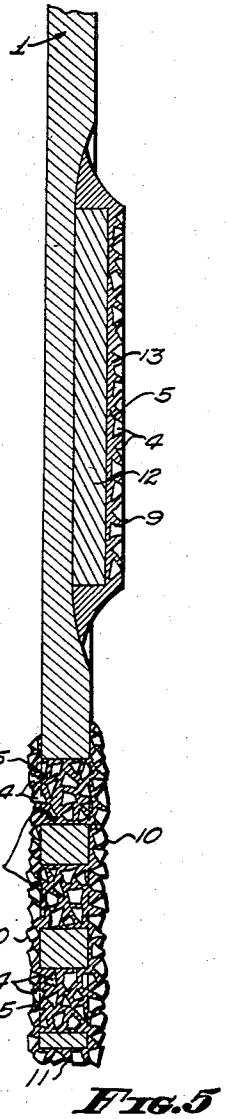


FIG. 5

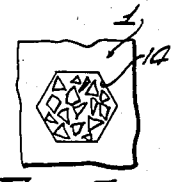


FIG. 7

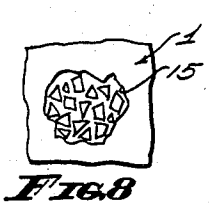


FIG. 8

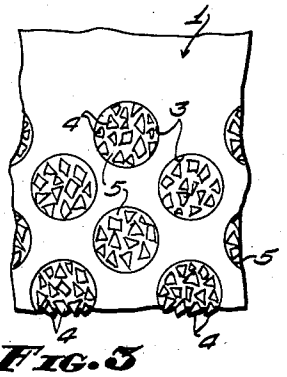


FIG. 5

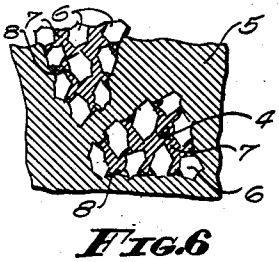


FIG. 6

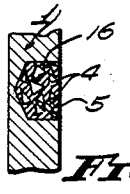


FIG. 9

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ANNULAR MILL FOR USE IN OIL WELLS

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10 Claims. (Cl. 255—72)

This invention relates to annular mills for use in oil wells, more particularly to mills used in washover operations wherein the axial end of the annular mill is used to cut an annular path between a stuck drill pipe, well tool, or other well fish, and the surrounding casing, so that the fish may be retrieved.

Included in the objects of this invention are:

First, to provide an annular mill of this type wherein the lower end of a tubular steel body member is provided with rings of perforations or sockets arranged in staggered relation, each perforation or socket being filled with cutting elements formed of tungsten carbide bound in a matrix and restrained by the surrounding walls of the body member.

Second, to provide an annular mill of this type wherein, as the end of the mill wears away, successive perforations are caused to intersect the axial end of the mill exposing the cutting elements therein for operation, the cutting facility of the mill is thus continuously renewed as one perforation is obliterated and cutting elements of another freshly exposed.

Third, to provide an oil well mill of this type wherein special surfaces are provided on the exterior or interior of the tubular body member, as desired, which include tungsten carbide elements bound in a matrix and so ground as to provide a bearing as distinguished from a cutting surface, whereby, for example, the mill may be guided by a surrounding casing without cutting into the walls of the casing.

Fourth, to provide an oil well mill which operates effectively irrespective of the shape of the fish or junk lodged in the oil well, or whether or not the obstruction is eccentrically disposed so that only a portion is within the cutting circle of the mill.

Fifth, to provide a mill of this type which, although especially intended for milling metal fish or junk, is capable of milling through cement or other solid matter which may surround the obstruction.

With the above and other objects in view, as may appear hereinafter, reference is directed to the accompanying drawings in which:

Figure 1 is a side view of an annular mill embodying the present invention;

Fig. 2 is an enlarged fragmentary sectional view taken through 2—2 of Fig. 1;

Fig. 3 is an enlarged fragmentary side view thereof, showing the annular mill partially worn away to expose the cutting elements;

Fig. 4 is a fragmentary sectional view similar to Fig. 2, showing a modified construction;

Fig. 5 is a fragmentary sectional view also similar to Fig. 2, showing a further modified construction;

Fig. 6 is a greatly exaggerated, substantially diagrammatical, fragmentary sectional view, showing the construction of the cutting elements and the manner in which the cutting elements are retained in a surrounding matrix;

Fig. 7 is a fragmentary side view similar to Fig. 3, showing a perforation of polygonal shape;

Fig. 8 is a similar fragmentary side view, showing a perfection of irregular shape as may be formed by a cutting torch;

Fig. 9 is a fragmentary sectional view similar to Fig. 2, showing a socket in place of a perforation.

The annular mill comprises a tubular body member 1 formed of steel or steel alloy and provided with a screw-threaded upper end 2 for connection to a drill string, not shown. The lower end of the body member 1 is provided with a pattern of perforations 3, preferably so arranged that any transverse plane within the region occupied by the perforations intersects a ring of perforations; that is, the rings of perforations axially overlap. Each of the perforations receive a plurality of cutting elements 4 which are embedded in a matrix 5.

The cutting elements 4 are cemented carbide particles which have been shattered or formed into desired shapes and selected as to size. Cutting elements varying from 3/64" to 1/4" are satisfactory. Each cutting element or particle comprises, as represented diagrammatically in Fig. 6, a plurality of grains 6 bonded by a cementing material 7, usually cobalt. A representative list of the cemented carbides which may be used include the carbides of tungsten, molybdenum, chromium, vanadium, zirconium, titanium, uranium, tantalum, and niobium (columbium).

It is preferred to use for the cutting element a cemented carbide particle having a Rockwell "A" hardness of 85 and above. Many of the commercially available cemented carbides are satisfactory. The principal commercial carbides are tungsten carbide in a binder of cobalt, or alloys comprising principally tungsten carbide with varying percentages of other carbides with cobalt as the principal binder.

In the case of cemented tungsten carbide or its alloys, it is essential to use mono-tungsten carbide (WC) as distinguished from di-tungsten carbide (W_2C). W_2C is extremely brittle and does not bond well, but instead is believed to form with the cobalt binder a brittle compound (possibly W_2CCo_2); and therefore has poor shock resistance. It readily shatters and fails to maintain a cutting edge. Its presence, even in comparatively small amounts, greatly detracts from the quality of the cemented carbide.

Conversely, WC has the desired hardness, and especially when properly bonded or cemented with cobalt or other appropriate bonding alloys of cobalt exhibits superior shock resistance. When WC is heated to its melting point it decomposes into graphite and a liquid, the composition of which is not certain. This liquid solidifies as a mixture of WC and W_2C with inclusions of the graphite formed when melted. It is therefore important that cemented carbides be used as opposed to cast carbides.

It is desirable in mounting the cutting elements within the perforations 3 that the temperature be maintained below the melting point of the binder in order to avoid injurious grain growth of the carbide grains and/or injurious dilution of the cementing material with the matrix. Thus it is preferred to select a matrix 5 which has a melting point in a range from about 1600° F. to 2450° F. and therefore comfortably below the melting point of the binder 7 (2728° F. for cobalt).

A wide range of matrix alloys, and compositions are suitable. Representative matrix materials include pure copper, copper-zinc alloys, copper-nickel alloys, copper-zinc-nickel alloys, copper-silicon alloys, and more complex alloys of copper which may include manganese, tungsten, iron, silver, cadmium, beryllium, cobalt, and other alloy metals of varying amounts. Also many of the commercially available nickel-chromium-boron alloys are satisfactory.

The desirable properties for the matrix 5 are that the

melting point be below the carbide binder; that the matrix wets the cemented carbide particles or cutting elements **4**; and that the matrix be tough, resilient, ductile, and wear-resistant, so as to provide a good shock barrier or shock cushion for the cemented carbide particles or cutting elements.

While it is desirable to avoid undue heating of the cemented carbide elements or fragments **6**, it is also desirable to maintain the matrix in a fluid state for a period sufficient to effect intergranular penetration of the binder **7**, as indicated by **8** in Fig. 6 wherein the cross-hatching representing the matrix **5** and the bonding material **7** is shown as overlapping to suggest the intergranular penetration. This may be accomplished in whole or in part prior to filling the perforations **3**; that is, a rod or bar may be formed by casting the matrix material around the cutting elements laid in a suitable cavity or by embedding the cutting elements in the matrix. The rod thus formed may be maintained at the proper temperature to effect the desired intergranular penetration of the matrix into the bonding material.

The rod thus formed is then welded or brazed into the perforations. The cutting elements and surrounding matrix completely fill the perforations. In the course of filling the perforations, appropriate commercial fluxes may be used to effect a bond between the matrix and the surrounding walls of the perforations. The cutting elements are thereby held by the matrix, and the matrix in turn is held by the material comprising the body member **1**. Thus a particularly firm support is assured for the cutting elements.

If it is desired that the cutting action be confined almost completely to the axial end of the annular mill, any radially protruding cutting elements or portions of matrix are ground until the surfaces of the matrix units in each of the perforations, as well as the cutting elements, are flush with the peripheral surfaces of the body member **1**. In so grinding or finishing the exposed surfaces of the cutting elements, these surfaces become bearing units **9** which are essentially noncutting. Thus when the annular mill is rotated within a surrounding casing, the surrounding casing remains undamaged.

In Fig. 2 both the radially inner and radially outer surfaces of the matrix and cutting elements are shown as ground flush with the peripheral surfaces of the tubular body member **1**. With this construction the body member, which may be made in any desired length, may be lowered over a drill string or tubing within a casing, for the purpose of cutting an obstruction between the two without damaging either the drill string or tubing, or the casing.

In many cases, however, it is desirable that either the inner periphery or the outer periphery of the annular mill be provided with a cutting surface. In this case, a continuous or uninterrupted sheath **10** of matrix is applied over the internal or external surface of the body member **1**, as the case may be, and filled with additional cutting elements **4**. In so applying the sheath **10**, a complete bond is established between the matrix comprising the sheath and the matrix contained within the perforations. If desired, an axial end sheath **11** comprising matrix and cutting elements may be provided, as shown in Fig. 4.

Still further, it may be desirable to provide cutting sheaths **10** on both the internal and external surfaces, as shown in Fig. 5. In this case, it may be desirable, in order to protect a surrounding casing, that an appropriate bearing surface be provided on the body member **1** above the cutting end thereof. This may be done by welding rudimentary ribs or cores **12** to the sides of the body member **1** and covering these cores with a bearing pad **13** formed of the matrix **5** and carbide particles **4**. In this case, the exposed surfaces of the particles **4** are ground to form bearing units **9**, as in the previously described structures.

While round perforations have been shown in Figs. 1 to 5, other shapes may be adopted as, for example, they may be polygonal as indicated by **14** in Fig. 7; or they may be formed by a cutting torch and thus be irregular in outline as indicated by **15** in Fig. 8. Still further, sockets may be employed as indicated by **16** in Fig. 9. Whether perforations or sockets are used, they form pockets for the reception of the matrix and cutting elements or fragments.

The operation of the annular mill is as follows:

The mill is lowered on a drill string into a well bore until its lower axial end engages the fish or other obstruction within the well bore. The mill is then rotated, preferably while drilling fluid is circulated downward through the drill string and upward through the annulus between the drill string and the surrounding casing. The matrix initially covering the cutting elements **4** at the axially lowered end of the body member **1** wears away, as does also the metal of the body member between the perforations. This exposes the cutting elements **4** as suggested in Fig. 3.

As the milling operation progresses, the cutting elements are progressively destroyed, and the matrix and material comprising the body member **1** wear away exposing additional cutting elements until the entire zone containing the cutting elements and matrix-filled perforations has been worn away. The rate of wear of the mill is, of course, far less rapid than the material which the mill encounters in the well bore. Thus before the mill is worn out many feet of metal within a well bore may be milled.

In many cases the fish or other obstruction is eccentrically located so that only a small segment of the annular mill is in contact with the fish. However, by reason of the fact that the teeth formed by the exposed and active cutting elements are relatively small, the mill does not hang up, or bind or chatter under such conditions. Although the mill is intended primarily for milling metal, it is also capable of milling cement or other solid material it may encounter within a well bore.

In the case of the construction shown in Figs. 1, 2, and 3, the cutting action is confined to the axial end of the mill, inasmuch as the ground faces of the cutting elements **4** which form the bearing units **9** have inherently excellent bearing qualities, even in the presence of abraiding material which may be flowing upwardly between the mill and the surrounding casing.

While particular embodiments of this invention have been shown and described, it is not intended to limit the same to the exact details of the constructions set forth, and it embraces such changes, modifications, and equivalents of the parts and their formation and arrangement as come within the purview of the appended claims.

What is claimed is:

1. A cutter for use within a well bore, comprising: a hollow tubular body member having a plurality of pockets arranged in a predetermined pattern adjacent one end thereof and dispersed around the entire periphery thereof, said end of the body mmeber arranged to wear away to intersect said pockets; a plurality of cutting elements consisting of bodies of cemented metal carbides disposed in each of said pockets; and a matrix metal embedding said cutting elements, and bonded both to said cutting elements and the walls of said pockets, whereby as said pockets are intersected by wear of said body member said cutting elements are exposed at said end of the body member.

2. A cutter as set forth in claim 1, wherein: said pockets are perforations extending completely through the walls of said body member.

3. A cutter as set forth in claim 1, wherein: said pockets are sockets closed at their bottom ends.

4. A cutter for use within a well bore, comprising: a tubular body member including means at its upper end

for attachment to a drill string, and a plurality of pockets adjacent its lower end and dispersed around the entire periphery thereof; a plurality of cemented metal carbide cutting elements in each of said pockets; and a matrix metal embedding said cutting elements and bonded thereto and to the walls of said pockets; said body member and said matrix being composed of materials softer than said cutting elements and tending to wear away upon rotation of said body member in forcible contact with a surface, thereby to cause the end of said body member to intersect said pockets and expose said cutting elements for cutting action against said surface.

5. A cutter as set forth in claim 4, wherein: said pockets are perforations extending completely through the walls of said body member.

6. A cutter as set forth in claim 4, wherein: said pockets are sockets closed at their bottom ends.

7. A cutter for use within well bores as set forth in claim 4, wherein: said pockets comprise perforations through the wall of said tubular body member, the radially inner and outer surfaces of the cutting elements and matrix filling said perforations are flush with the radially inner and outer surfaces of said body member and the flush surfaces of said cutting elements form noncutting bearing areas.

8. A cutter for use within well bores as set forth in claim 4, wherein: said pockets comprise perforations through the wall of said tubular body member, one of the peripheral surfaces of said body member is provided with a coating of matrix and cutting elements are embedded therein, said matrix coating being bonded with the matrix filling said perforations; and wherein the surface of the matrix and the surfaces of the cutting elements therein, exposed to the other peripheral surface of the body member, are flush therewith, and said flush surfaces of the cutting elements form noncutting bearing areas.

9. A cutter for use within well bores as set forth in claim 4, wherein: said pockets comprise perforations through the wall of said tubular body member, the radially inner and radially outer peripheral surfaces of said body member are provided with a coating of matrix integral with the matrix filling said perforations, and cutting elements are embedded in said matrix coating.

10. A cutter for use within well bores as set forth in claim 4, wherein: said pockets comprise perforations through the wall of said tubular body member, the radially inner and radially outer peripheral surfaces of said body member are provided with a coating of matrix integral with the matrix filling said perforations and cutting elements embedded in said matrix coating; and wherein bearing elements are provided on peripheral surfaces of said body member which project radially beyond said cutting elements for supporting said body member for rotation relative to a companion member.

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