June 14, 1960 J. W. TAYLOR ET AL 2,940,522

CUTTING TOOL

Filed March 5, 1957 2 Sheets-Sheet 1

Fig. 1

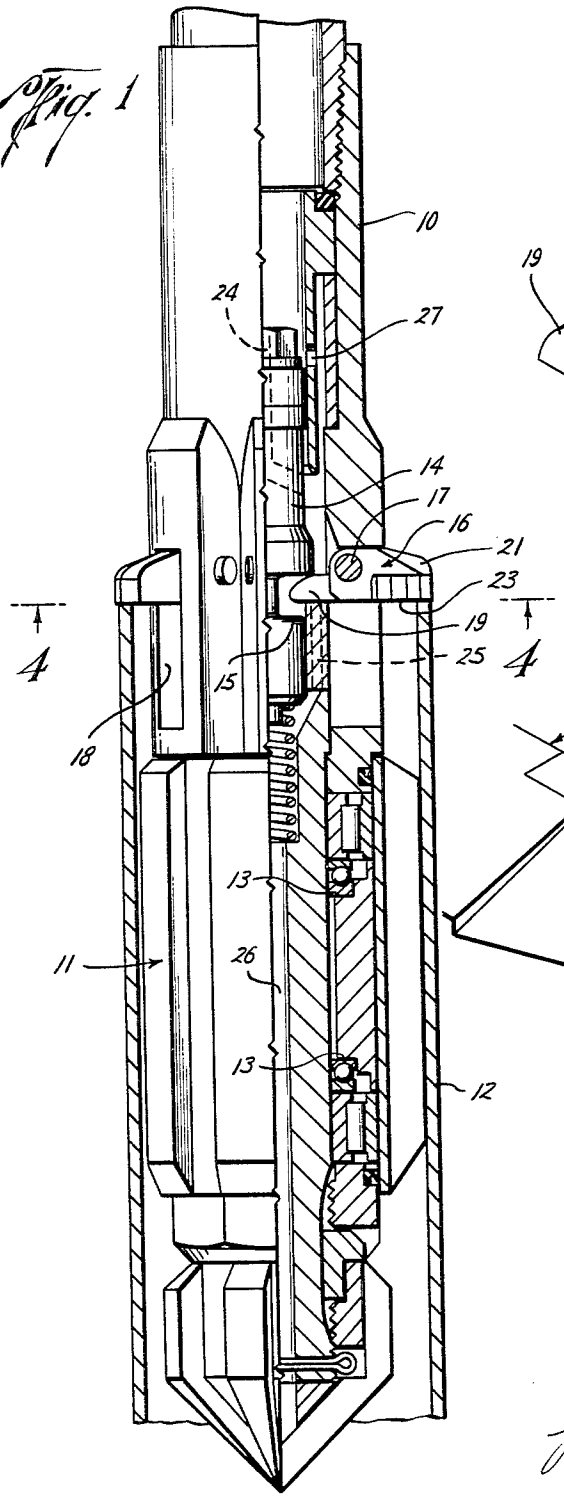


Fig. 2

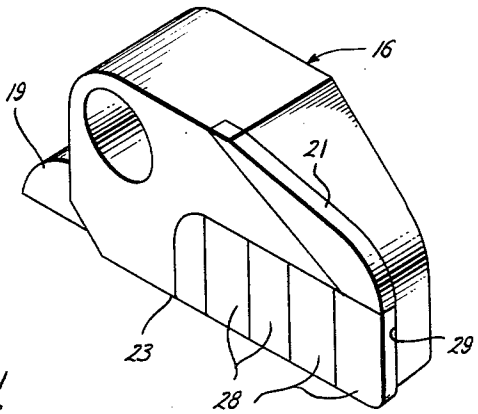
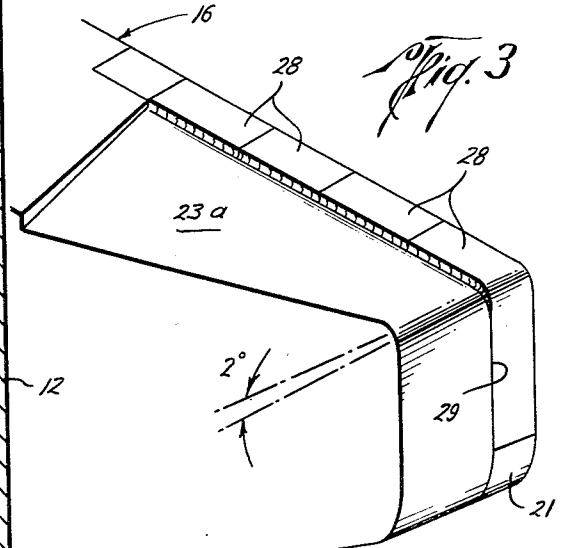


Fig. 3



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June 14, 1960 J. W. TAYLOR ET AL 2,940,522

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Filed March 5, 1957 2 Sheets-Sheet 2

Fig. 4

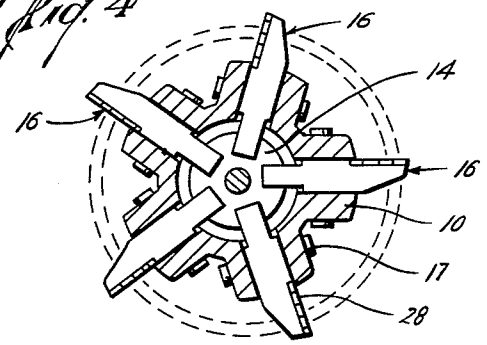


Fig. 7

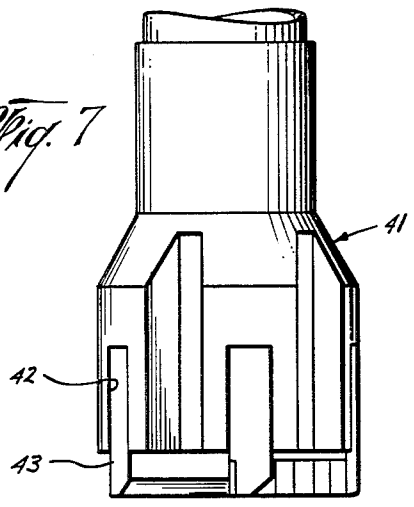


Fig. 9

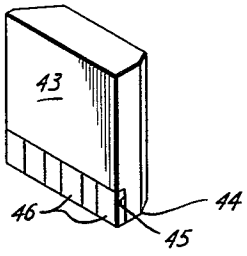
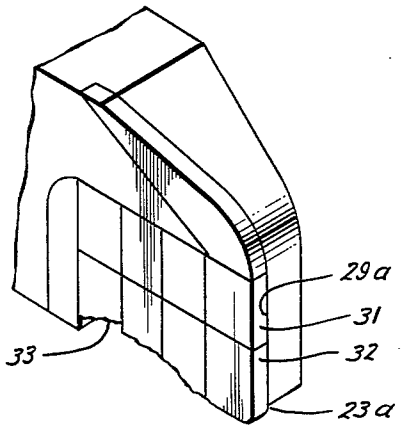


Fig. 5



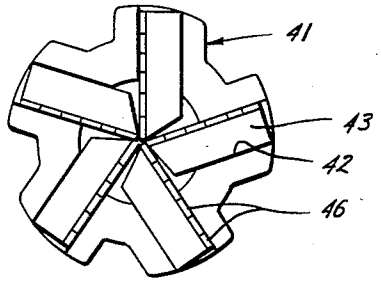
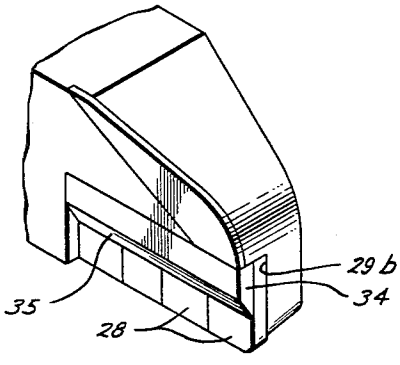


Fig. 8

Fig. 6



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CUTTING TOOL

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5 Claims. (Cl. 166—55)

This invention relates to tools for cutting down in the bore of a well and more particularly to tools for cutting out a section of well casing or cutting out obstructions in the well such as a stuck packer.

In the drilling and production of petroleum wells, it is frequently necessary to cut out a section of casing. This may be done to expose a well formation during production of the well. It also may be done during drilling of the well to permit sidetracking operations, that is, drilling around some undesirable condition such as a cavernous formation which has been encountered. It is also sometimes necessary to drill out an obstruction in a well bore.

In the past, it has been necessary to use steel cutters for both the end mills and casing mills. No practical way has been devised for tipping the cutters with very hard cutting material such as the cemented carbides. As the hard cutter tips are also characterized by being very brittle, they tend to break off in use. In previous attempts to use hard cutters, it has been found that in breaking the fracture line sometimes runs in a direction to render a cutter substantially useless. This condition cannot be tolerated due to the expense of pulling the tool from the well to replace the cutter. The necessity of using hardened steel cutters has made window cutting and end milling in wells a slow tedious process which frequently requires two or more sets of cutters to mill out a window of the desired size for sidetracking.

By this invention there are provided both an end mill and a casing cutter which successfully employ hard brittle cutting tips of cemented carbide or the like.

By this invention we provide a tipped cutter in which fracturing of one tip does not destroy the entire effectiveness of the cutter. This is of particular advantage when the tipped cutter is used in conjunction with a casing mill utilizing the principles taught in the Earl J. Robishaw Patent No. 2,690,217, issued September 28, 1954. This patent provides for the eccentric rotation of the casing mill so that the knives move radially while cutting casing. By this invention we provide a knife in which crumbling away of a cutter tip will only impair the cutting efficiency of a small radial distance of the cutter and the cutter will continue to function.

We have found that cutters for end mills and casing cutters may be provided with knives employing rows of separate small slabs of hard cutting material such as the cemented carbides and that knives so tipped will stand-up under the heavy loads imposed in modern day milling. When one of the tips fractures or breaks away to provide a new cutting edge, the fracture line will not extend to adjacent tips and, therefore, a bad fracture line will effect only a small portion of the cutting edge of the cutter.

Use of mills constructed in accordance with this invention have raised new problems. For most efficient cutting the load on the cutters should be very high. This results in chips of large size which are hard to pump to the surface. Many of the chips will be spirals of several

inches in length. A number of these chips could gather in one area in the well and cause difficulty.

By this invention we provide a chip breaker which turns the chips back on themselves as they are cut and forces them to break off of the workpiece in small pieces.

It is an object of this invention to provide an end mill or casing cutter for use in wells which will cut much more rapidly than those heretofore in use.

Another object of this invention is to provide a milling tool for use in wells such as an end mill or a casing cutter which successfully employs very hard brittle cutting tips.

Another object of this invention is to provide an end mill or casing cutter for wells employing cemented carbide cutting tips.

Another object is to provide an end mill or casing cutter for wells employing self-sharpening cemented carbide cutters.

Another object is to provide an end mill or casing cutter for wells employing cemented carbide cutters which progressively break off to provide new sharp cutting edges in which it is impossible for the fracture line to extend completely across the cutting face of the cutter.

Another object is to provide a cutting tool having cemented carbide cutters which are supported to permit their use under very high force conditions and in which the support and carbide are gradually worn and broken away to successively provide new cutting edges.

Another object is to provide a casing cutter which rotates about an axis eccentric to the casing being cut in which the cutters or knives are provided with tips of very hard brittle material which crumble and break off in use and yet in which each crumbling of each tip is localized and effects only a short section of the cutting face of the cutter.

Another object is to provide an end mill or casing cutter for use in wells with a chip breaker which limits the size of the chips cut.

Other objects, features and advantages of this invention will be apparent from the drawings, the claims and the specification.

In the drawings wherein there is shown by way of illustration several embodiments of this invention and wherein like reference characters are used throughout to designate like parts:

Fig. 1 is a vertical sectional view through a casing being cut by a casing mill therein with the casing mill shown partly in elevation and partly in vertical cross section;

Fig. 2 is a perspective view of one of the cutters of the casing mill;

Fig. 3 is a perspective view of a fragment of the cutter of Fig. 2 on an enlarged scale and in an inverted position;

Fig. 4 is a view along the lines 4—4 of Fig. 1;

Fig. 5 is a perspective view of a fragment of a modified form of cutter;

Fig. 6 is a perspective view of a fragment of a still further modified form of cutter;

Fig. 7 is an elevational view of an end mill constructed in accordance with this invention;

Fig. 8 is a bottom plan view of the end mill of Fig. 7; and

Fig. 9 is a perspective view of one of the cutter inserts of the end mill of Fig. 7.

Referring first to Fig. 1, the casing mill illustrated is substantially identical with the casing mill shown in Patent No. 2,690,217, issued to E. J. Robishaw on September 28, 1954, with the exception of the construction of the individual cutters or blades. Reference is made to the Robishaw patent for a full description of the several components of the mill and the functions thereof.

In general, the mill includes a body **10** having an

eccentric guide assembly indicated generally at **11** on its lower end. As shown in this figure and in Fig. 4, the guide assembly causes the mill to rotate about an eccentric axis relative to the casing **12** which is being cut by the tool. This eccentric rotation causes the knives to move radially in cutting and provides a much greater area of each cutter for effective cutting of a window in a casing as well as minimizing the tendency of the cutters to groove and increase their bearing area in engagement with the casing being cut.

The eccentric assembly is provided with a bearing assembly **13** which permits the eccentric assembly to rotate relative to the body **10**.

When the cutter is run in the hole, the actuator piston **14** is in a raised position relative to that shown in the drawing. In this position, the groove **15** is higher and the cutters **16** are rotated about their pivot **17** and are within the slots **18** of the mill. When the tool is in the proper position within the well, fluid is pumped down through the drill string and acts against the piston to move it downwardly. As it moves downward, the cam portion **19** of each cutter is engaged by the slotted piston and the cutters are urged radially outward of the mill. While the cutters are urged radially outward by fluid pressure, the mill is rotated and the cutting surface **21** of each cutter **16** bears against the inner wall of the casing **12** and cuts an annular window therethrough. As this window is cut, the pressure on the piston **14** moves it down to the position illustrated in the drawings and the knives **16** are extended radially until their undersurface **23** extends substantially perpendicular to the casing **12**. Further rotation of the tool will cause a section of the pipe **12** to be cut out. It will be noted that the body **10** bears against the cutters **16** at a point intermediate the pivot **17** and the casing **12** being cut and, therefore, considerable force may be exerted on the string to force the cutters against the workpiece.

Before the knives penetrate through the casing, fluid circulation is provided through the piston passageway shown in dashed lines at **24**. Fluid passes from the piston out through the slots **18** and down through the dotted passageway **25** to the bore **26** in the lower end of the tool and thence out the bottom of the tool. This fluid washes cuttings to the surface. After the piston **14** moves down into the position shown, a plurality of lateral ports **27** are uncovered which permits an increase in the volume of fluid passing through the tool and indicates to the operator that the initial window has been cut and he may apply pressure to the string to begin cutting a section out of the casing.

Referring now to Figs. 2 and 3, there is shown the preferred form of cutter **16**. The cutter **16** is formed in more or less the usual general configuration of cutters employed in this service. For cutting the initial window in the pipe, the cutting surface **21** is provided by an inlay of high grade cutting steel.

The undersurface **23** of the cutter **16** provides the cutting face for cutting the section out of a pipe and when making this cut, faces endwise of the tool as shown in Fig. 1. The actual cutting done by the cutting face **23** is done by a plurality of hard cutters **28**. These cutters are provided from the group of cutting tips which are so very hard that they are brittle and, therefore, give trouble when subjected to high shock loads such as normally encountered with a casing mill. It will be appreciated that the load on the cutters **16** is so high that they are actually bent. This is particularly true when the knives or cutters first break through the casing wall as the cutters may then hang in the window until the lower edge of the window is smoothed by the action of the cutting surface **23**.

This high shock load and bending factor normally encountered has prevented the use of cutting tips of the very hard brittle material in the past.

The hard brittle material referred to above may be any of the well known cutter tips used in tipping tools generally such as the cemented carbides. Tungsten carbide tips are preferred for this service.

The brittleness of the cutting tips is both an advantage and a disadvantage. In use they tend to fracture and crumble away at the cutting edge and this presents new sharp cutting edges which is desirable. However, the fracture line may be such as to remove a large chunk of the tip and impair or destroy the effectiveness of the particular cutter. Further, it is preferred to secure the tips to the cutters by welding and as the base metal of the cutter and tips have different coefficients of expansion, the residual differential stresses remaining after the weld has been completed are such that a large carbide tip will be popped off of the cutter when subjected to heavy shock load.

The above problems have stymied the past attempts to use hard brittle tips in casing cutters. These problems are solved by the cutters illustrated in the drawings by using a plurality of slabs of hard brittle cutting material **28**.

The slabs of cutting material are arranged in a row with edges of the several slabs contiguous with each other and with each slab having one edge terminating at the cutting face **23** of the cutter. As there are a number of slabs providing the cutting face of the cutter, any fracture line in one of the slabs which causes loss of the cutting surface provided by the particular slab will not extend to the adjacent slabs. Therefore, an unfortunate fracture will effect only a small portion of the cutting edge of the cutter. Of course, as the cutter wears down, the residue of the slab which had a large chunk broken off will again come into play and be effective.

Running of a casing cutter in a deep hole requires a number of hours due to the time necessary to make up the drill string for a distance of many thousand feet. Therefore, it is highly desirable that the individual cutters of the casing mill be capable of cutting out the complete section of the casing desired before they are worn through. With this factor in mind, it is desired that the individual slabs of hard material extend away from the cutting face **23** of the cutter as far as possible. However, as pointed out above, the maximum dimension of the slabs **28** is limited by setting up of undesirable stress loads during the welding process. Therefore, they should not be long enough to give rise to these undesirable stress loads in the welding process. In passing it might be mentioned that it is preferred to weld the slabs to the cutter with brazing material so that the temperatures involved in fabricating the cutter will not be sufficient to injure the cutter tips.

It is also preferred to normalize the knives at a reduced temperature after the slabs are brazed in place.

In thickness, the slabs **28** should be such that they are difficult to break but will break after the slabs become dull.

By way of example a typical insert for a 9⅝ inch casing mill may have the following dimensions: ⅛ inch thick, ¾ of an inch high, and ⅜ of an inch in width.

In the preferred form of this invention, a groove is provided in the cutting face **23** of the cutter as by notching the leading face of the cutter at **29**. This notch **29** is dimensioned to receive the several slabs **28** with their exterior faces flush with the periphery of the cutter.

It has been found that the base metal portion **23***a* of the cutting face **23** will wear away to approximately a two degree bevel commencing at the slabs of hard material. The hard material will also project slightly beyond the base metal at the juncture between the slabs and base metal. Therefore, it is preferred to form the knife with the base metal portion of the cutting face at a two degree bevel so that the knife may begin cutting immediately with full efficiency and not have to wait for wearing away of the base metal to gain full efficiency.

In use it has been found that the best performance

will be obtained when the knife is loaded with sufficient force to cause the slab tips to bear against the casing being cut with a force exceeding the yield strength of the casing. Use in this manner probably accounts for the wearing away of the base metal to the two degree bevel as pointed out above. In actual use, cutters constructed in accordance with this invention have successfully milled casing having a yield strength in excess of 100,000 lbs. per square inch.

Referring to Fig. 5, there is shown a modified form of cutter for use with the mill of Fig. 1. As pointed out above, the maximum dimension of the carbide is limited as it is desired to avoid excessive stresses resulting from the welding of the carbide to the cutter. To increase the life of the cutter, it is in some cases desirable to have tips which extend away from the cutting face 23*a* a greater distance than possible with one row of tips. In these circumstances, a second row of tips indicated generally at **31** may be provided on the side of the first row of tips indicated generally at **32** remote from the cutting face **23***a*. In this cutter, the groove **29***a* is formed of a sufficient size to receive the two rows of tips.

Fig. 5 also illustrates the general manner of wear of the cutters when used in the casing mill of Fig. 1. At **33** there is illustrated the manner in which a tip may break off and render a section of the cutter inoperative due to the fracture line of the break removing a large slab of the tip. However, this does not render ineffective the entire knife and as the knife wears this broken slab will again become effective.

Referring now to Fig. 6, there is shown a further modified form of this invention in which the size of the cuttings resulting from use of the casing mill is controlled. It has been found that the cuttings produced by the mill when employing the Fig. 2 form of cutter will frequently be spirals of as much as from four to six inches. It is preferred to maintain the cuttings of as small a size as possible to avoid any possibility of their fouling the casing cutter or drill string and for this purpose a chip breaker is provided. The chip breaker may be provided by any means which will precede the cutting tips **28** and engage the chips as they are cut to force them to break off in small pieces. In the preferred form illustrated in Fig. 6, the chip breaker is provided by a metallic bar **34** secured over the leading face of the several tips **28** and having a surface **35** positioned to engage a chip as it is curled up by action of the tips **28**. It is preferred that the surface **35** be beveled as shown and the metal from which the chip breaker is formed should be such that it will gradually wear away at substantially the same rate at which the tips **28** wear. In this way it will retain substantially the same relationship to the cutting face of the cutters at all times. The groove **29***b* may be recessed sufficient to receive both the tips **28** and the chip breaker **34** if desired.

Referring now to Figs. 7 through 9, there is shown an end mill equipped with this invention. The end mill body **41** is formed in more or less conventional style. Notches **42** are provided in the bottom face of the mill to receive replaceable knives **43**. As in conventional end mills, these knives extend from approximately the center of the tool radially outward to its outer edge so that they are capable of milling away anything inside of the bore hole which is blocking the hole. The cutting face **44** of each of the knives **43** is provided at its leading edge with a recess **45**. A plurality of slabs **46** of hard brittle material such as tungsten carbide are positioned in a row in the groove **45**. These slabs are arranged in the same manner as in the casing mill with adjacent edges contiguous to each other and with one edge terminating at the cutting face **44** of the knife. Again the several slabs extend away from the cutting face **44** a sufficient distance to provide for wear of the knives and yet are not sufficient in size to set up undesirable stresses when the slabs are welded to the knives.

It is frequently necessary to spud the mill to break up fish in a well which are free to rotate and, therefore, cannot be cut by rotation of the tool. While the spudding operation tends to cause breakage of the slabs **46**, it has been found that this breakage is not overly severe and the tipped tool is vastly superior to the conventional untipped tool.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects herein above set forth, together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it it to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. A well tool for cutting tubular goods in a well comprising, a tool body having a lower end, a cutter body mounted on the tool body to extend laterally of the tool body and having a leading face and also having a cutting face facing the lower end of the tool body, a plurality of slabs of cemented metal carbide secured in a row to the leading face of the cutter body and positioned so that each slab has one end adjacent said cutting face, said slabs also being positioned in close side-by-side relationship with respect to each other with substantially no space existing between adjacent sides of adjacent slabs so that said slab ends together form a substantially continuous cutting edge for cutting contact with the tubular goods to be cut.

2. The tool of claim 1 wherein said slabs are in abutment along adjacent sides of adjacent slabs.

3. The tool of claim 1 wherein there is a second row of slabs secured to the leading face of the cutter body, said second row extending parallel to the first-mentioned row and positioned on the side of the first-mentioned row remote from said cutting face.

4. The tool of claim 1 wherein chip breaker means are attached to the cutter for engaging a chip cut by the slabs to turn the chip back toward the surface being cut.

5. The tool of claim 4 wherein said chip breaker means is a member carried by the cutter body in front of the slabs and having an upwardly and outwardly inclined surface spaced from the cutting face and positioned to engage a chip cut by the slabs and turn the chip back toward the surface being cut.

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