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2,644,673

EXPANSIBLE ROTARY DRILL BIT AND CUTTER

Filed Sept. 26, 1949

2 Sheets-Sheet 1

Fig. 1.

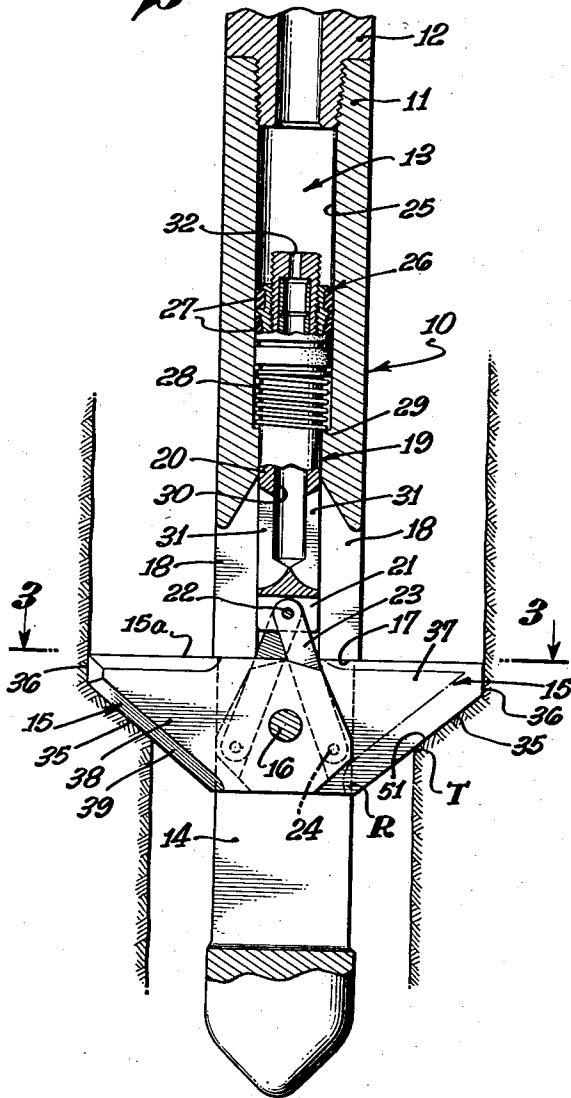


Fig. 2.

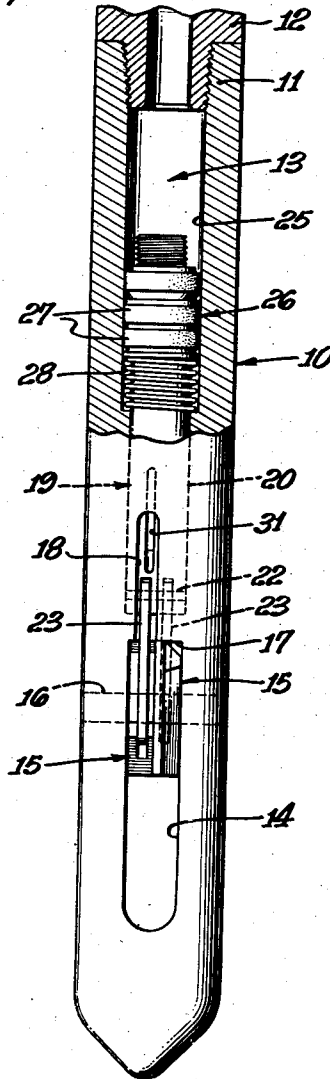
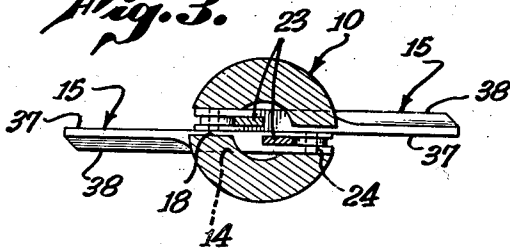


Fig. 3.



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Fig. 4.

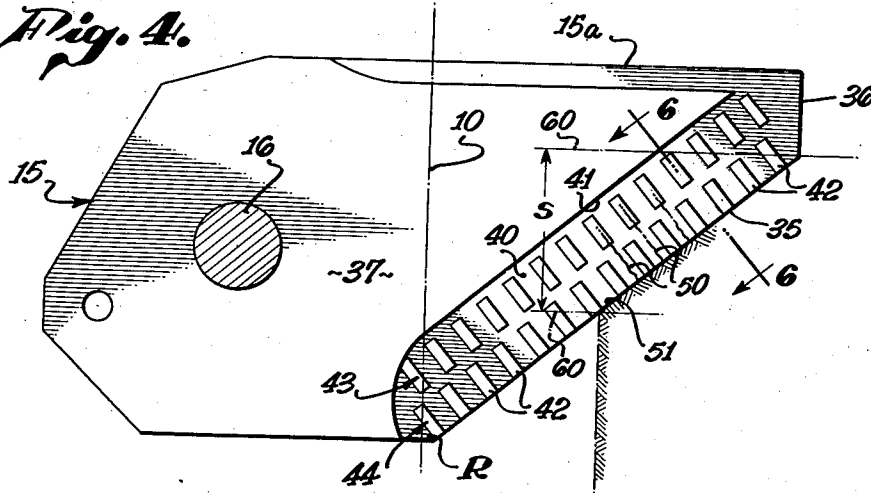


Fig. 5.

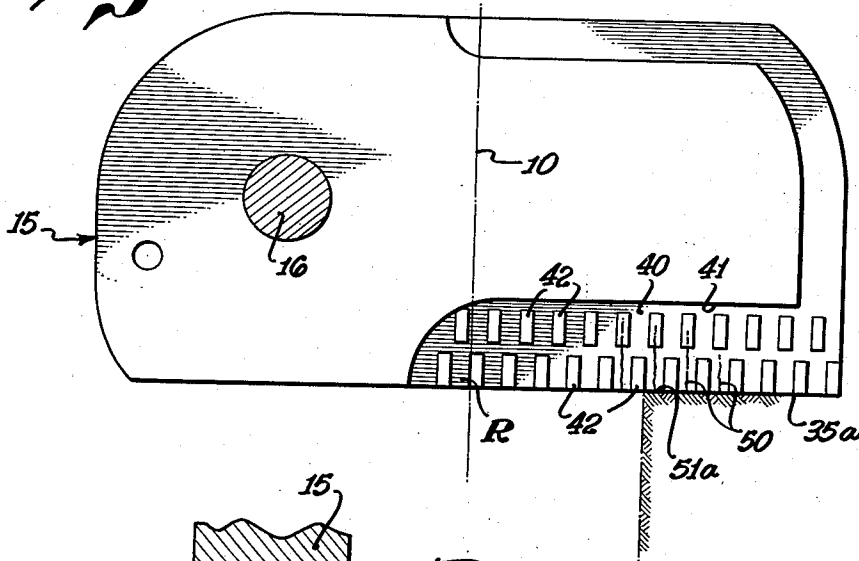
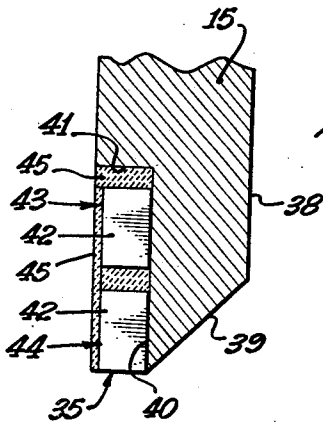


Fig. 6.



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EXPANSIBLE ROTARY DRILL BIT AND CUTTER

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5 Claims. (Cl. 255—76)

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The present invention relates to drill bits, and more particularly to bits having one or more cutters movable between retracted and expanded positions.

Rotary drill bits of the drag type are known for enlarging the diameter of well bores below a casing string. These bits may include one or more cutters or blades mounted on the bit body initially in retracted position, the blades being expanded outwardly when disposed below the lower end of the casing string to increase the well bore diameter upon rotation of the drill bit. Hardfacing materials may be applied to the blades, after which the hardfaced blades are heat treated. These operations result in the formation of small cracks in the hardfaced surfaces of the blades, which are often the source of fatigue and other types of failures. Former shapes of blades have also contributed to blade failure as the result of the concentration of the loads imposed upon the blades. Moreover, the cutter blades do not operate smoothly in certain formations, and may have sudden shock loads imposed upon them during their rotation in the well bore.

Accordingly, it is an object of the present invention to improve cutter blades of the drag type employed in expansible rotary drill bits.

Another object of the invention is to minimize the presence of cracks in the surfaces of rotary drill bit blades which are hardfaced.

A further object of the invention is to provide a cutter blade for an expansible rotary drill bit which is more flexible than blades heretofore used, and which has better shock resistance.

Still another object of the invention is to distribute the load imposed on the cutter blade over a substantially larger portion of the blade.

Yet a further object of the invention is to provide an expansible rotary drill bit embodying blades that operate smoothly in enlarging the diameter of the well bore.

Another object of the invention is to provide an expansible drill bit embodying cutter blades that tend to keep the bit centered in the well bore.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

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Referring to the drawings:

Figure 1 is a longitudinal section through an expansible rotary drill bit or rotary underreamer, with its cutter blades in expanded position for operation in a well bore;

Fig. 2 is a side elevation, partly in section, of the drill bit shown in Fig. 1;

Fig. 3 is a cross-section taken along the line 3—3 on Fig. 1;

Fig. 4 is a front elevation, on an enlarged scale, of the leading face of one of the cutter blades;

Fig. 5 is a front elevation of another cutter blade that can be used in a rotary drill bit of the type disclosed in Fig. 1;

Fig. 6 is an enlarged fragmentary section taken along the line 6—6 of Fig. 4.

Underreamers of the type disclosed in the drawings are described in detail in United States Patent No. 1,857,616. They include an elongate main supporting body 10 provided with an upper threaded box 11 attachable to the lower end of a string of drill pipe 12 or the like, by means of which the underreamer is lowered in the well bore and rotated in the performance of its underreaming operation. The body has a central longitudinal passage 13 therethrough, merging into diametrically opposed elongate slots 14 opening outwardly of the body. A pair of cutter blades 15 of the drag type are movable within the slots, being mounted upon a hinge pin 16 extending through the body and across its passage 13.

The cutters 15 have an initial downward position substantially completely retracted within the confines of the body 10, and are swingable outwardly in opposite directions to extend beyond the periphery of the body, occupying a generally horizontal position, with their upper sides 15a engaging the upper shoulders 17 of the longitudinal slots 14. A second set of longitudinal slots 18 extend upwardly to one side of and above the stop shoulders 17 at the ends of the main slots, to provide passages through which drilling fluid may pass for discharge onto the cutter blades 15.

The blades are swingable inwardly and outwardly of the body slots 14 in response to upward and downward movement of an operating plunger 19 slidable within the central passage 13 of the main body. This plunger includes a tubular plunger body 20 having a transverse hole through depending legs 21 in its lower end for receiving a pivot pin 22, in which the upper ends of a pair of links 23 are pivotally mounted between the legs. The lower end of each link is pivotally attached to a cutter blade 15 by means of a pin 24. It is to be noted that the links 23 are pivoted to the blades on opposite sides of

the hinge pin 16, in order that downward movement of the plunger 19 pivots the blades 15 oppositely in upward and outward directions. Such outward movement may continue, as aforementioned, until the blades occupy horizontal positions in contact with the body shoulders 17.

The upper end of the body passage 13 is enlarged in diameter to form a cylinder 25 slidably receiving the upper piston portion 26 of the plunger, which is also enlarged to a diameter greater than the lower plunger body portion 20. A plurality of piston rings 27, of rubber or similar material, are mounted on the piston for slidable sealing engagement with the wall of the cylinder 25 to prevent leakage in both directions around the piston. A spring 28 encircles the smaller diameter plunger body portion 20, one end engaging the lower end 92 of the cylinder and its other end engaging the piston 26. This spring is under compression and tends to elevate the plunger 19 and retract and maintain the blades 15 in their inward position within the confines of the body 10.

The plunger 19 is movable downwardly and the blades expanded outwardly by the pressure of fluid, like drilling mud, pumped downwardly through the string of drill pipe 12, and acting upon the piston 26. Since it is desired to discharge the drilling fluid onto the cutters 15 to maintain them free of detritus, the fluid continues downwardly through a central passage 30 in the plunger 19 for discharge in opposite directions through elongate slots 31 in the lower portion of the plunger body, and through the upper body slots 18 onto the forward cutting faces of the cutter blades. In view of this discharge of fluid, an orifice or restriction 32 is provided in the plunger passage 30 to enable a back pressure to be built up on the high pressure side of the piston 26, sufficient in value to overcome the compressive force of the spring 28, shift the plunger 19 downwardly, and swing the blades 15 outwardly, through the agency of the pin and link connections 22, 23, 25 between the plunger 19 and blades 15.

From the drawings, it is to be noted that each cutter blade 15 has a lower cutting edge 35 that is inclined in an upward and outward direction when the blade is expanded to its horizontal position. When in this position, the outer edge 36 of the blade has a substantial longitudinal extent; so as to have adequate bearing against the formation wall.

The lower inclined edge 35 extends from a point R adjacent the bit body 10 to the outer edge 36 of the blade, and preferably makes a substantial angle with the horizontal. As an example, the angle may be forty degrees, although wide variations from this angular extent can be made, depending upon the length of the blade in a horizontal direction. Assuming that the blade is quite long, so as to greatly enlarge the well bore diameter, the angle which the lower inclined edge makes with the horizontal will be less. As an example, a lesser angle is obtained if blades are used that extend horizontally outwardly eighteen inches from the pivotal axis about the pin 16.

Each blade has a flat leading face 37 and also a flat trailing face 38. The lower inclined edge 39 of the trailing face is beveled, terminating at the lower end of a recess 40 formed along the inclined leading edge 35 and extending from the outer edge 36 to approximately the point R along the blade within the body slot 14. The

upper wall 41 of this recess may be generally parallel to the inclined lower edge 35. The upper edge 15a may also be provided with a similar recess extending from the outer edge 36 inwardly towards the body 10.

Hardfacing material is welded to the parent metal of each blade within the recess 40. Such hardfacing material may include "peas" or particles of tungsten carbide 42 that may be placed in two rows 43, 44, one above the other and substantially at right angles to the inclined cutting edge 35 of the blade. As an example, each pea may be about $\frac{3}{8}$ -inch by $\frac{1}{4}$ -inch by 1-inch and they may be placed in the recess 40 spaced about $\frac{5}{8}$ -inch apart. The upper row 43 may be staggered with respect to the lower row 44. These peas 42 are welded within the recess 40 to the parent metal of the blade by the use of a welding rod which is preferably in the form of a tube containing tungsten carbide of a suitable mesh (say eight to thirty mesh). This tube of tungsten carbide 45 is applied between and over the "peas" 42 until substantially the entire recess 40 has been filled. Thereafter, if desired, another layer of suitable welding material can then be applied over the peas 42 and finer mesh tungsten carbide 45 for the purpose of filling any porosity that may remain after the tube rod has been used.

The hardfacing material may be applied in the recess 40 running along the lower inclined cutting edge 35, along the outer edge 36 and also along the upper cutting edge 15a. After its application, the leading face 37 of the blade may be suitably ground to present a smooth surface and to insure proper swinging movement of the blade about the pivot pin 16 during its shifting between retracted and expanded positions.

The sheath of hardfacing materials applied to the blade has a different thermal coefficient of expansion than that of the parent blade metal. As a result, cracks 50 in the hardfacing appear after the blades are finish ground. These cracks apparently occur during the hardfacing operation, or during the subsequent heat treatment to which the blades are subjected. These cracks are usually normal to the cutting edge 35 and are points of stress concentration, despite the fact that they may or may not originally penetrate into the parent metal. These cracks also appear in the hardfacing material at the point R in the blade lying near or within the body slot 14.

After the expansible drill bit has been lowered in the well bore to a point below the casing string at which the hole enlarging operation is to take place, the pumps at the top of the well bore are started and the string of drill pipe 12 and drill bit are rotated at the proper speed. Pressure of the fluid on the piston 26 urges the latter downwardly and swings the blades 15 in opposite directions outwardly about the hinge pin 16. The upper edges 15a of the blades first engage the formation and begin enlarging the hole. Eventually, the blades have been expanded outwardly to their horizontal position, whereupon drilling weight may be imposed on the drill string and bit to cause the lower leading edge 35 to form a frusto-conical shoulder 51 in the formation, the inclination of the shoulder being essentially the same as the degree of inclination of the leading edge 35 to the bit and hole axis. The proper drilling weight is applied to the tool during its rotation, the fluid exiting from the tool to maintain its blades free of cuttings.

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and to carry the cuttings upwardly around the drill pipe 12 to the top of the well bore.

Each blade 15 is actually in the nature of a cantilever beam, the greatest bending moment on the blade being at the point, or along the line, where the blade enters the body, or at the periphery of the body 10.

Blades can be used having lower cutting edges 35a disposed substantially at right angles to the axis of the bit body (see Fig. 5). The recess in which the hardfacing materials 42, 45 are applied are also disposed along this lower edge and extend partly into the bit body. The cracks 50 developed as the result of applying the hardfacing material, and the subsequent heat treatment, are disposed at right angles to the lower cutting edge 35a, or generally parallel to the axis of the bit. These cracks also are on the blade portion disposed within the body, since the hardfacing material extends part way into the body slot 14. Such blades formed a shoulder 51a in the well bore that is normal to the bit axis. As a result, substantially all of the load imposed on each cutter blade is concentrated along its lower cutting edge 51a and is transmitted to the body of the bit at the point R where the edge enters the body slot 14. At this point, the bending moment and shear stresses are the greatest. The parent metal of the blade is of reduced diameter section at this point of stress concentration, because of the provision of the recess 40, and the crack or cracks 50 in the hardfacing material at this point, which may or may not initially extend into the parent metal, form loci where blade failure can occur. Rotation of the bit and operation of the blades upon the formation shoulder 51a imposes severe shock loads on the blades, resulting in blade failure, usually at the point R where the blades enter the body 10.

Thus, the blades of the design shown in Fig. 5 have the reactive drilling torque imposed thereon in a direction generally in line with the hardfacing cracks 50. This torque is concentrated in the blade along its lower cutting portion 35a. The remainder of the blade contributes very little to withstanding the stresses to which the blade is subjected. In addition, the generally rectangular shape of the blade makes the blade comparatively rigid and non-flexible, rendering it less able to withstand shock loads imposed upon it.

As distinguished from the generally rectangular blades, applicant provides his hardfacing material 42, 45 along an inclined lower cutting edge 35. The hardfacing "peas" 42 are disposed normal to this lower edge, which also results in the cracks 50 extending normal to this inclined edge. The blade forms an inclined shoulder 51 in the formation, and not merely a shoulder at right angles to the axis of the bit body. As a result, the reactive torque imposed upon each blade is not transmitted to the body merely at a comparatively small locus R where the lower portion of the blade enters the body, but is transmitted throughout a substantial longitudinal extent of the blade to the body. By referring to Fig. 4, it becomes evident that the reactive torque imposed on the cutter blade 15 during its drilling of the inclined formation shoulder 51 is transmitted along a substantial length S of the blade, which may extend generally between the broken lines 60, this torque being transmitted along substantially the entire length of the blade to the bit body 10.

Thus, the reactive torque is not localized at a

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comparatively small point (as: R) where hardfacing cracks, or deep hardening cracks resulting from heat treatment, may be present, and where the parent metal of the blade has a lesser section. The blade can, therefore, be subjected to substantially greater loads without danger of its failure, especially at the point of greatest stress concentration adjacent the periphery of the bit body. In addition, the blade is not prone to failure at any of the other cracks 50 along its lower edge 35, since the forces associated with the torque being transmitted do not coincide with or act parallel to the cracks, cutting diagonally across them.

By tapering the cutting edge 35 of the blade, the blade is made more flexible than a straight blade, because its section modulus varies across the blade substantially directly in proportion to the bending moment imposed upon it. Since the blade is more flexible, it has better shock resistance than a straight blade (as in Fig. 5), and is less susceptible to breaking when sudden shock loads are imposed upon it. As a matter of fact, the inclination of the blade reduces the imposition of shock loads upon it, since the tapered edge 35 attacks any hard shells, or other hard formations, from a point T closer to the bit body, the edges 35 gradually working out on the shell to the outer edge 36 of the blade. Blades having straight lower edges (Fig. 5) at right angles to the bit body contact such hard shells at the outer ends 36a of the blades first, where the moment arm is greatest and where the shock loads have the maximum effect upon the blade at its point R of greatest stress concentration adjacent the periphery of the bit body 10.

Not only do the tapered blades minimize the opportunities for imposing shock loads on the blades, but they also result in the formation of a downward and inwardly inclined shoulder 51 on the formation for cooperation with the tapered blades, to keep the tool centered, as well as making it run smoother.

The inventor claims:

1. In an expansible rotary drill bit: a main body; a cutter blade; means pivotally mounting said blade on said body; means for swinging said blade between a retracted position substantially entirely within said body and an expanded position extending substantially outwardly of said body; said blade having a lower cutting portion providing a lower edge continuously inclined substantially to the body axis in a downward and inward direction when the blade is in expanded position; said inclined portion having a recess formed in the leading face of the blade and extending upwardly from said lower edge and also extending from a point adjacent said body to the outer edge of the blade; and hardfacing elements in said recess welded to said blade, said elements being arranged substantially normal to the lower inclined edge of said blade.

2. In an expansible rotary drill bit: a main body; a cutter blade; means pivotally mounting said blade on said body; means for swinging said blade between a retracted position substantially entirely within said body and an expanded position extending substantially outwardly of said body; said blade having a lower cutting portion providing a lower edge continuously inclined substantially to the body axis in a downward and inward direction when the blade is in expanded position; said inclined portion having a recess formed in the leading face of the blade and extending upwardly from said edge and also

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extending from a point adjacent said body to the outer edge of the blade; and a plurality of rows of hardfacing elements in said recess welded to said blade, said elements of one row being staggered with respect to the elements of another row and said elements of said rows being arranged substantially normal to the lower inclined edge of said blade.

3. In an expansible rotary drill bit: a main body having a longitudinal slot; a pair of cutter blades in said slot; means pivotally mounting said blades on said body; means for swinging said blades in opposite directions between retracted positions substantially entirely within said body slot and expanded positions extending in opposite directions substantially outwardly of said body; each of said blades having a lower cutting portion providing a lower edge continuously inclined substantially to the body axis in a downward and inward direction when the blade is in expanded position; said inclined portion having a recess formed in the leading face of the blade and extending upwardly from said lower edge and also extending from a point adjacent said body slot to the outer edge of the blade; hardfacing elements in said recess welded to said blade, said elements being arranged substantially normal to the lower inclined edge of said blade.

4. A flat, elongate cutter blade for an expansible rotary drill bit having a hole therein for mounting said blade on a bit body, said blade having a lower cutting portion of extended length providing a lower edge continuously inclined in a downward and inward direction from the outer portion of said blade toward the inner portion of said blade; said inclined portion having a recess formed in the leading face of the blade and extending upwardly from said lower edge and also extending from the outer edge of the blade inwardly a substantial distance toward

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the blade hole, and hardfacing elements in said recess welded to said blade, said elements being arranged substantially normal to the lower inclined edge of said blade.

5. In an expansible rotary drill bit: a main body; a cutter blade; means pivotally mounting said blade on said body; means for swinging said blade between a retracted position substantially entirely within said body and an expanded position extending substantially outwardly of said body; said blade having a lower cutting portion providing a lower edge continuously inclined substantially to the body axis in a downward and inward direction when the blade is in expanded position; said inclined portion having a recess formed in the leading face of the blade and extending upwardly from said lower edge and also extending from a point adjacent said body to the outer edge of said blade; hardfacing elements in said recess; said elements being arranged substantially normal to the lower inclined edge of said blade; and hardfacing material welding said elements to said blade in said recess.

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