A durable, weld-on tooth for roll crushers is provided. The tooth includes a cast high-carbon steel body having multiple transverse grooves for receiving tungsten carbide inserts, which are silver brazed into the grooves. The tungsten inserts are located on the surfaces of the tooth that are most susceptible to wear from abrasive action of the coal as the roll crusher operates. The cast carbon steel body can be directly welded to the exterior cylindrical surface of a rotary roll crusher. For a preferred embodiment of the tooth, the front and side faces of the cast high-carbon steel body have bevels that enable weldments that secure it to the roll crusher drum to be somewhat recessed beneath the cast high-carbon steel body on three sides thereof.
BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to teeth for roll crushers and, more particularly, to teeth which are welded to the outer surface of roll crusher drums.

[0003] 2. Description of the Prior Art

[0004] Roll crushers are compression type crushers widely used extensively in mining operations. There are two basic types of roll crushers. The first employs a single roll operating adjacent a curved stationary anvil plate. The second employs two counter-rotating rolls having parallel axes and a gap between the rolls. Particle output size is determined, in the case of a single roll crusher, by the gap between the roll and the anvil plate or, in the case of a double-roll crusher, by the gap between the rolls. During the operation of a roll crusher, large particles are drawn into the gap by the rotating motion of the roll or rolls and a friction, or nip, angle formed between either the single roll and its adjacent anvil plate or between the two rolls of the double-roll crusher and the particle. As the large particles are forced into an ever smaller gap, compressive forces fracture the particles. Roll crushers have a theoretical maximum reduction ratio of 4:1. Thus, if an 8-inch diameter particle is fed to the roll crusher the absolute smallest size one could expect from the crusher is a 2-inch diameter particle.

[0005] Though once widely used to crush mined mineral-containing rock, the use of roll crushers in that application has declined during the past decade as low-cost, low-maintenance cone crushers have largely taken over the task. However, because the output from roll crushers has a very narrow size distribution and very little dust or fines is produced during the crushing process, roll crushers are still widely used in coal mining operations. Whereas roll crushers used to crush mineral and metal ores have smooth faced rolls, those used for crushing coal have teeth or other topography attached to the rolls.

[0006] If a coal seam is not too far beneath the surface, the coal is most easily mined with the greatest percentage of coal recovery by removing the overburden to expose the coal seam and, then, blasting and removing the coal. This is known as surface mining. Surface mining of coal has become widespread where coal seams are relatively close to the surface. The ratio of overburden excavated to the amount of coal removed is called the overburden ratio. The lower the ratio, the more productive the mine. The lowest overburden ratios are found in western surface mines. In Appalachia, often more than one coal seam is mined.

[0007] There are several types of surface coal mines. Area surface mines, usually found in flat terrain, consist of a series of cuts 100 to 200 feet wide. The overburden from one cut is used to fill in the mined out area of the preceding cut. Contour mining, occurring in mountainous terrain, follows a coal seam along the side of the hill. When contour mining becomes too expensive, additional coal can often be produced from the mine's highwall by the use of augers or highwall miners. Open pit mines are usually found where coal seams are thick, and can reach depths of several hundred feet.

[0008] Equipment used in surface mines include draglines, shovels, bulldozers, front-end loaders, bucket wheel excavators and trucks. In large mines, draglines remove the overburden while shovels are used to load the coal. In smaller mines, bulldozers and front-end loaders are often used to remove overburden. However, when it coal seam is too far beneath the surface to make surface mining practical, underground mining is used.

[0009] If it is not practical to remove the overburden covering a coal seam, the seam must be mined using underground mining methods. Most underground coal is mined by the room and pillar method, whereby rooms are cut into the coal bed leaving a series of pillars, or columns of coal, to help support the mine roof and control the flow of air. Generally, rooms are 20-30 feet wide and the pillars up to 100 feet wide. As mining advances, a grid-like pattern of rooms and pillars is formed. When mining advances to the end of a panel or the property line, retreat mining begins. In retreat mining, the workers mine as much coal as possible from the remaining pillars until the roof falls in. When retreat mining is completed, the mined area is abandoned. There are two methods to extract the coal using room and pillar mining: conventional mining and continuous mining. Conventional mining is the oldest method, and now accounts for only about 12% of underground coal output. In conventional mining, the coal seam is cut, drilled, blasted and then loaded into cars. Continuous mining is now the most prevalent form of underground mining, accounting for about 56% of total underground production. In continuous mining, a machine known as a continuous miner cuts the coal from the mining face, obviating the need for drilling and blasting.

[0010] The longwall method of underground coal mining, which was implemented during the latter half of the twentieth century, is generally considered to represent the most revolutionary advance in coal mining technology in history. Longwall mining now accounts for about 31% of underground coal production. There are about 100 longwall operations in the United States, with most of them being in Appalachia. In longwall mining, a cutting head moves back and forth across a panel of coal about 800 feet in width and up to 7,000 feet in length. The cut coal falls onto a flexible conveyor for removal. Longwall mining is done under hydraulic roof supports (shields) that are advanced as the seam is cut. The roof in the mined out areas falls as the shields advance. About ninety percent of the coal within a seam is recoverable using the method.

[0011] Roll crushers are typically used to treat the output of both surface mines and underground mines so that lumps of the mined coal measure no more than 5.0 cm (about 2.0 inches) across. This is generally the maximum size that coal-fired power plants are willing to accept. Such crushers are generally of the dual-roll type, and are manufactured by companies such as Joy Mining Machinery, Inc. and McLanahan Corporation. The crushers typically utilize a rotary drum to which teeth are affixed. U.S. Pat. No. 4,807,820 to Theodore F. Gundlach discloses a segmental shell for a coal crusher roll. The teeth are clearly visible on the segmental shell of the drawings.

[0012] In the interest of permanently securing the teeth to crusher rolls, teeth are welded to the cylindrical surface of the crusher roll. Although welding the teeth to the roll greatly enhances overall durability of the roll, replacing worn-out or broken teeth is no simple task. When the drum is rebuilt, the worn-out teeth must be cut from the outer surface of the drum, and new teeth welded to the drum to replace those that have been cut off. The process is labor intensive and costly. Clearly,
the longer the life expectancy of the attached teeth, the longer the drum can be productively used, and the less the downtime required for rebuilding the drum.

Four basic types of teeth are presently manufactured for use on crusher rolls. The first type is a cast steel tooth having hard facing welded on the wear surface. Each tooth of this type sells for about $15.00. In continuous service, such a tooth lasts only about four weeks.

The second type of tooth is a cast steel tooth having tungsten carbide chips welded onto the wear surface. Each tooth of this type sells for about $35.00. The problem with this type of tooth is that after the tungsten carbide chips are worn off, the tooth becomes rounded and stops crushing the coal. In continuous service, such a tooth lasts only about 12 weeks.

The third type of tooth is a cut steel tooth having a welded-on cast mild steel bar with tungsten carbide chips cast into the wear face. This type of tooth also includes welded-on hard facing. Each such tooth sells for about $48. This type of tooth suffers from a number of drawbacks: the casting of tungsten carbide chips is a slow and difficult process, resulting in high manufacturing costs; and when the tungsten carbide chips are worn off, the tooth is, effectively, unusable. In continuous service, a tooth of this type also lasts about 12 weeks.

The fourth type of tooth is a mild steel tooth having tungsten carbide chips cast into the wear face. The primary problem with this type of tooth is cost, as the casting of tungsten carbide chips is a difficult and slow process. The chips are gravity fed into the molten mild steel as the casting is poured. The process results in the presence of chips only on the face of the tooth. Although each tooth of this type sells for about $54.00, it lasts only about 12 weeks in continuous service.

The focus of the present invention is the manufacture of a more durable tooth that greatly extends the useful life of the rotary drums used in roll crushers.

SUMMARY OF THE INVENTION

The present invention provides a durable tooth which can be welded directly to the outer cylindrical surface of the drum of a roll crusher. The tooth includes a cast carbon steel body having multiple transverse grooves for receiving tungsten carbide inserts, which are silver brazed into the grooves. For a preferred embodiment of the tooth, the cast carbon steel body is made of #7018 carbon steel. The silver brazing alloy joins the materials and compensates for the difference in their expansion rates. In addition, it provides a cushion between the ultra-hard tungsten carbide inserts and the hard steel body, which softens impacts and minimizes damage to the inserts. The tungsten inserts are located on the surfaces of the tooth that are most susceptible to wear from abrasive action of the coal as the roll crusher operates. The cast carbon steel body 100 can be directly welded to the exterior cylindrical surface of a rotary roll crusher.

Though the use of metal alloy containing up to 40 percent silver as a molten joining compound is colloquially referred to as silver soldering, the process is more accurately described as silver brazing. In the U.S., soldering is traditionally defined as the joining of two components using a metal alloy which has a melting point below 800° F. (427° C.). Though silver brazing is similar to soldering, the filler metal has a significantly different composition. Common silver brazing alloys contain as much as 60% silver or as little as 20%, with the remainder made up of metals including copper, zinc, nickel, and tin. Silver brazing alloys melt at temperatures as low as 1145 F. There are several grades of silver solder, and some flow more easily than others (it is the silver which provides the free-flowing characteristics). Even though silver brazing compounds are very adept at filling small caps through capillary action, they should not be relied on to fill large gaps between joined components, as joint strength drops off rapidly as the gap between the joined components increases. As a consequence of this reality, the gaps between two components of any silver brazed joint should be no greater than 0.125 mm (about 0.005 inch) and, ideally, no greater than half that amount. Such tolerances are typically achieved through surface grinding of the mating surfaces. In addition, interference fits between components to be joined must be scrupulously avoided, as capillary action will be hindered, and joint integrity will be significantly damaged. The silver alloy filler compound is brought slightly above its melting (liquidus) temperature while protected by a suitable atmosphere or flux. It then interacts with a thin layer of the base metal (known as wetting) and is then cooled rapidly to form a sealed joint. By definition, the melting temperature of the braze alloy is lower—often, substantially lower—than the melting temperature of the materials being joined. Brazed joints are generally stronger than the individual metals making up the filler alloy due to both the geometry of the joint and the metallurgical bonding that occurs at the interface of each base metal component and the filler alloy. At the interface, a very thin matrix of filler metal atoms and base metal atoms is formed. In order to maximize the strength of brazed joints, base metal parts must be exceptionally clean and free of oxide.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of the cast carbon steel roll crusher tooth before installation of the beveled tungsten carbide bars within the grooves;

FIG. 2 is an isometric view of a single beveled tungsten carbide bar;

FIG. 3 is an isometric view of the completed cast carbon steel roll crusher tooth having multiple beveled tungsten carbide bars silver soldered to grooves in the wear faces thereof;

FIG. 4 is a front elevational view of the completed cast carbon steel roll crusher tooth;

FIG. 5 is a side elevational view of the completed cast carbon steel roll crusher tooth;

FIG. 6 is a top plan view of the completed cast carbon steel roll crusher tooth;

FIG. 7 is a bottom plan view of the completed cast carbon steel roll crusher tooth; and

FIG. 8 is a rear elevational view of the completed cast carbon steel roll cruiser tooth.

DETAILED DESCRIPTION OF THE INVENTION

The invention will now be described with reference to the attached drawing FIGS. 1 through 8. It should be understood that although the drawings are intended to be merely illustrative, a reasonable attempt has been made to provide drawings which are close to scale.

Referring now to FIG. 1, a tooth body 100 is cast from #7018 high-carbon steel. It will be noted that the tooth body 100 has a vertical, generally planar front face 101; a vertical, generally planar right-side face 102; an upper surface 103 that has a generally planar forward portion 103F and
a simple-curved rear portion 103R that begins at the level of the planar forward portion 103F, and transitions so as to make an acute-angled rear edge 104 with a planar lower surface 701 (please refer to the bottom plan view of FIG. 7). The left-side face 102S (please refer to FIG. 5) is a vertical, generally planar surface and a mirror image of the right-side face 102D. For a preferred embodiment of the invention, the cast carbon steel body 100 is about 5.1 cm (2.0 inches) in height, 3.8 cm (1.5 inches) in width, and 7.6 cm (3.0 inches) in length. The tooth body 100 is equipped with three transverse grooves 106A, 106B, and 106C in an upper portion of the front surface 101 and the planar forward portion 103F of the upper surface 103. Although the grooves are formed as part of the casting process, they are preferably precision ground following the casting process to more exacting tolerances. In addition, the cast high-carbon steel tooth body 100 has 20-degree weld bevels 107F, 107D, and 107S on the lower edges of the front face 101, the right face 102D and the left face 102S, respectively. These bevels, which are about 6.35 mm (¼ inch) in width, allow weldments joining the cast carbon steel body 100 to a roll crusher drum to be somewhat recessed beneath the cast high-carbon steel body 100 around all but the acute-angled rear edge 104 portion of the perimeter thereof.

[0030] Referring now to FIG. 2, a single tungsten carbide insert 200 is shown. It will be noted that the insert is a generally rectangular block 201 having a crushing face 202 with chamfered edges 203 and a central notch 204. Each tungsten carbide insert 200 is manufactured to close tolerances. It will be noted in drawing FIG. 3 through 8 that each groove of the carbon steel body holds a single tungsten carbide insert 200. A single tungsten carbide insert 200 will be silver brazed into each of the three transverse grooves 106A, 106B, and 106C in the cast high-carbon steel body 100. Though the use of metal alloy containing up to 40 percent silver as a molten joining compound is colloquially referred to as silver soldering, the process is more accurately described as silver brazing. In the U.S., soldering is traditionally defined as the joining of two components using a metal alloy which has a melting point below 800° F. (427° C.). Though silver brazing is similar to soldering, the filler metal has a significantly different composition (between 20 and 50 percent silver) and a melting temperature above 450° C. (842° F.). There are several grades of silver alloy brazing compound, and some flow more easily than others (it is the silver which provides the free-flowing characteristics). Even though it is very adept at filling small gaps through capillary action, silver alloy brazing compound should not be relied on to fill large gaps between joined components, as joint strength drops off rapidly as the gap between the joined components increases. As a consequence of this phenomenon, the gaps between each transverse groove 106A, 106B, and 106C and its associated tungsten carbide insert 100 should be no greater than 0.125 mm (about 0.005 inch) and, ideally, no greater than half that amount. These tolerances are achieved by precision grinding both the transverse grooves 106A, 106B, and 106C, as well as each tungsten carbide insert 200. Interference fits between each groove 106A, 106B or 106C and its associated tungsten carbide insert 200 must be scrupulously avoided, as capillary action will be hindered, and joint integrity will be significantly damaged. The silver alloy filler compound is brought slightly above its melting (liquidus) temperature while protected by a suitable atmosphere or flux. It then interacts with a thin layer of both the high-carbon steel body 100 or the tungsten carbide insert 200 of the base metal (known as wetting) and is then cooled rapidly to form a sealed joint. By definition, the melting temperature of the braze alloy is lower—often, substantially lower—than the melting temperature of the materials being joined. Brazed joints are generally stronger than the individual metals making up the filler alloy due to both the geometry of the joint and the metallurgical bonding that occurs at the interface of each base metal component and the filler alloy. At the interface, a very thin matrix of filler metal atoms and base metal atoms is formed. In order to maximize the strength of brazed joints, base metal parts must be exceptionally clean and free of oxide.

[0031] Referring now to FIGS. 3 through 8, the high-carbon steel body 100 and three tungsten carbide inserts 200-A, 200-B and 200-C have been joined as a single unit.

[0032] The new cast carbon steel tooth having beveled tungsten carbide inserts silver brazed in grooves within the wear faces is projected to have a unit price of about $64.00 and last about 26 weeks in continuous service. This represents about a 33 percent increase in cost and about a 100 percent increase in durability compared to the prior art cut steel tooth having the mild steel bar with tungsten carbide chips cast into the wear face is a mild steel tooth having tungsten carbide chips cast into the wear face. Compared to the mild steel tooth having cast-in tungsten carbide chips in the wear face, the cast carbon steel tooth having beveled tungsten carbide inserts silver soldered to the wear face is about 19 percent most costly, but about twice as durable.

[0033] Although only a single embodiment of the invention has been shown and described, it will be obvious to those having ordinary skill in the art that changes and modifications may be made thereto without departing from the scope and the spirit of the invention.

What is claimed is:
1. A wear-resistant tooth weldable to a drum of a roll crusher, said tooth comprising: a carbon steel body having a plurality of transverse grooves on surfaces thereof most susceptible to wear; and a tungsten carbide insert installed and silver brazed in each transverse groove, each carbide insert extending an entire width of said cast carbon steel body.
2. The wear-resistant tooth of claim 1, wherein said carbon steel body is cast from #7018 carbon steel.
3. The wear-resistant tooth of claim 1, wherein each transverse groove is cast into said carbon steel body.
4. The wear-resistant tooth of claim 3, wherein each transverse groove is precision ground, following casting of said body, for an optimum fit with its associated tungsten carbide insert, so that clearances between said tungsten carbide insert and each transverse groove are within a range of about 0.006 mm to 0.125 mm.
5. The wear-resistant tooth of claim 1, wherein said carbon steel body is about 5.1 cm in height, 3.8 cm in width, and 7.6 cm in length.
6. The wear-resistant tooth of claim 1, wherein said carbon steel body has generally vertical front and side faces, a generally planar lower surface, and an upper surface which tapers to make an acute-angled transverse rear edge with said lower surface.
7. The wear-resistant tooth of claim 6, wherein each of said faces is equipped with a bevel adjacent said lower surface which permits weldments to a roll crusher drum that are at least partially recessed.
8. The wear-resistant tooth of claim 7, wherein each of said bevels is about 6.5 mm in width and made an angle of about 20 degrees from each vertical face.

9. The wear-resistant tooth of claim 1, wherein said plurality of transverse grooves numbers three.

10. The wear-resistant tooth of claim 6, wherein said plurality of transverse grooves numbers three, a first transverse groove is made on said front face, a second transverse groove is made at an intersection of said front face and said upper surface, and a third transverse groove is made on said upper surface.

11. The wear-resistant tooth of claim 6, wherein said upper surface comprises a generally forward planar portion and a simple-curved rear portion.

12. A wear-resistant tooth weldable to a drum of a roll crusher, said tooth comprising:
   a carbon steel body having a generally planar vertical front face, generally planar side faces, a generally planar lower surface, and an upper surface perpendicular to said side faces which tapers to make an acute angled edge with said lower surface, said carbon steel body also having a plurality of transverse grooves on surfaces thereof most susceptible to wear; and
   a tungsten carbide insert installed and silver brazed in each transverse groove, each carbide insert extending an entire width of said cast carbon steel body.

13. The wear-resistant tooth of claim 12, wherein said carbon steel body is cast from #7018 carbon steel.

14. The wear-resistant tooth of claim 12, wherein each transverse groove is cast into said carbon steel body.

15. The wear-resistant tooth of claim 14, wherein each transverse groove is precision ground, following casting of said body, for an optimum fit with its associated tungsten carbide insert.

16. The wear-resistant tooth of claim 12, wherein said carbon steel body is about 5.1 cm in height, 3.8 cm in width, and 7.6 cm in length.

17. The wear-resistant tooth of claim 12, wherein said carbon steel body has generally vertical front and side faces, a generally planar lower surface, and an upper surface which tapers to make an acute-angled transverse rear edge with said lower surface.

18. The wear-resistant tooth of claim 17, wherein each of said faces is equipped with a bevel adjacent said lower surface which permits weldments to a roll crusher drum that are at least partially recessed.

19. The wear-resistant tooth of claim 12, wherein said plurality of transverse grooves numbers three, and a first transverse groove is made on said front face, a second transverse groove is made at an intersection of said front face and said upper surface, and a third transverse groove is made on said upper surface.

20. The wear-resistant tooth of claim 17, wherein said upper surface comprises a generally forward planar portion and a simple-curved rear portion.

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