DRAWING AND IRONING PROCESS

Prior to the drawing and ironing of a sheet or blank of a material such as untinned low carbon cold rolled steel to form a tubular article such as a can body, the metal sheet is roughened in such manner as to provide an overall, uniformly dense pattern of minute depressions in its surface. Oil or other lubricant is applied to the roughened surface and is retained within these small depressions during the drawing and ironing operation, whereby to reduce the mechanical and frictional forces on the blank and on the drawing and ironing dies and thus eliminate galling of the dies and minimize fracture of the metal.

3 Claims, 3 Drawing Figures
DRAWING AND IRONING \process

BACKGROUND AND EXPLANATION OF THE INVENTION

One of the most successful processes presently being utilized for forming deep, seamless container bodies from flat blanks is known as the drawing and ironing process and involves first drawing the blank into shallow cup form in one or more drawing operations and thereafter thinning and elongating the sidewalls of the cup in one or more ironing operations.

The drawing dies usually produce a relatively shallow cup having blank thicknesses substantially equal to the original thickness of the blank. Thereafter, the ironing dies thin the sidewall of the drawn cup and cause retrograde flow of the metal, thereby increasing the height of the cup while leaving the thickness of its bottom substantially unchanged. If desired, a drawing or redrawing die may be designed to also function as an ironing die, as for example disclosed in our U.S. Pat. No. 3,203,218, granted on Aug. 3, 1965.

As used herein, the term “drawing” means the forming of recessed parts by forcing the plastic flow of metal in, and refers to the operation wherein a peripheral margin of a flat blank is turned inwardly and simultaneously smoothed by means of a drawing punch and die to form a cup having a wrinkle free sidewall whose thickness is substantially equal to the thickness of the original blank, while “ironing” means a thinning of the sidewall of a drawn cup by forcing the cup through tools wherein clearance between punch and die is less than the thickness of the sidewall. In an ironing operation, the sidewall of the cup is elongated by reducing its thickness with no reduction in the inside diameter of the cup. It is generally accomplished by placing the cup on a closely fitting punch and forcing the cup and punch through an ironing or thinning die whose thickness is slightly less than the outer diameter of the cup, thereby forcing the excess metal back and producing a longer but thinner sidewall. This ironing operation imposes severe frictional stresses on the metal of the cup, and if proper lubrication of the ironing die is not effected, some of the metal of the cup is deposited on the die. This metal build-up, or galling, sooner or later results in the tearing or fracture of the cups as they are forced through the die.

While the drawing and ironing process has been used extensively in the manufacture of seamless containers from blanks having surfaces which have a self-lubricating property, such as made of aluminum, or steel electrocoated with a softer ductile material such as tin as disclosed in our U.S. Pat. No. 3,360,157, granted Dec. 26, 1967, difficulty has been encountered in utilizing this technique in the manufacture of seamless containers from steel blanks having no ductile metallic coating. This is thought to be due principally to the fact that uncoated steel surface serves little or no lubricating function as the blank is forced through the ironing dies, and the lubricant which is applied to the blank is wiped off by the upper edge of the ironing die and thus does not properly lubricate the die face or the blank during the ironing operation. Since the ironing process subjects such blanks to extreme mechanical deformation and friction, galling of the ironing die and the consequent fracture of the blank results.

It has been found that this can be minimized, or substantially eliminated, if the surface of the steel blank is roughened in such manner as to form small shallow pockets which function as small reservoirs, while lubricant which is applied to the blank prior to, and sometimes during, the drawing and ironing operations. These reservoirs, while reduced in size, remain in existence throughout the drawing operations and throughout all or most of the ironing operations, and thus make available the lubricant which reduces the friction between the die faces and the blank surfaces, and thus greatly facilitate the ironing operation by minimizing spoilage and increasing the height to which the blank may be ironed without tearing of its metal.

While the principles of this invention may provide benefits when used with other types of metal stock, it is primarily useful when used with steel stock which is not provided with a surface coating or a more ductile metal such as tin. For the purpose of this invention, such steel stock will be referred to as uncoated stock or black plate, and includes various types of stock known in the trade as T.F.S. (tin free steel), some of which do bear extremely thin flash coatings of chromium or chromium compounds which do not have the ability to function as or become impregnated with a lubricant for ironing. The preferred manner of effecting the roughening is by sand blasting the metal stock with a fine gritty material such as sand or aluminum oxide in such manner as to obtain a uniform, dense pattern of small depressions. These depressions are gradually reduced in depth, or ironed out, during the formation of the container body, but it is desirable that they be of sufficient depth so that they are not completely eliminated until the need of lubrication no longer exists. Thus, as a general rule, the depressions should remain in existence, in gradually shallowing form, during all ironing operations, although it is desirable for purposes of appearance of the finished body that they be finally eliminated in the final ironing operation. However, it is necessary that they be of sufficient depth, as they enter this final ironing operation, to hold sufficient lubricant to prevent galling of the final ironing die.

The sand blasting of the metal stock is preferably performed on the sheet or web from which the blank bodies are cut, prior to the blanking operation, since there is a tendency for warpage to occur if the individual blanks are sand blasted. In addition, both sides of the stock are preferably sand blasted in order to minimize warpage.

While the primary need for lubricant is on the outside surface of the side wall of the cup in order to prevent galling of the ironing dies, it has been found that the roughening of the inner surface of this sidewall is very desirable to reduce friction between the cup and the punch, and thus facilitate stripping of the drawn and ironed cup from the punch. Despite this, the roughening of only the outer surface of the blank is still a substantial advance in the art, since in some instances the roughening of the interior is not necessary.

It will be understood that while the benefits of the invention are applicable to the drawing operation, they are not essential to it, whereas they are absolutely essential to the ironing operations. Thus, it would be possible to first draw the shallow cup from unroughened stock in a conventional drawing operation and then sand blast and lubricate either one or both surfaces of the walls of the cups prior to the ironing operations, which would be effected in a press separate from the drawing press. However, present commercial practice makes it most feasible to roughen the flat blank prior to both the drawing and ironing operations.

While sand blasting, which term for the purposes of this invention is used to describe a process wherein any suitably gritty particulate material, which may or may not be sand, is projected against the blank to roughen its surface, is the preferred method of roughening the blank, the invention is not so limited, and other methods, such as acid etching, mechanical abrasion by means of rolls or brushes, etc., may be utilized.

An object is to provide a practical method of drawing and ironing a thin-walled, cup-shaped steel container from uncoated steel stock.

A further object is to provide a method of drawing and ironing an uncoated steel blank without galling of the dies or fracture of the stock.

A still further object is to provide a method of forming a drawn and ironed container from uncoated steel wherein adequate lubrication during the ironing steps may be readily and easily accomplished.

Numerous other objects and advantages of the invention will be apparent as it is better understood from the description, which, taken in connection with the accompanying drawings, discloses a preferred embodiment thereof.
SUMMARY OF THE INVENTION

In drawing and ironing an article from a flat blank made from a material such as uncoated low-carbon sheet steel, the steel is treated by blasting its surface with a gritty material such as aluminum oxide or sand to provide a uniformly roughened surface containing a high density of minute depressions. The pre-roughened blank is then placed in a drawing and ironing press where a punch forces it through a drawing die to form it into a shallow, seamless cup. Thereafter, the sidewall of the drawn cup is forced through one or more ironing dies which thin and elongate the sidewall. Prior to the drawing operation and especially prior to the ironing operations, the blank is coated with a lubricant, and sufficient lubricant is retained in the small depressions of the roughened surface during these forming operations to reduce the mechanical and frictional forces between the blanks and the drawing and ironing dies. There is thus produced a drawn and ironed one-piece uncoated steel container having a seamless sidewall whose thickness is less than the end wall.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary perspective view of a marginal edge portion of a steel blank having its top and bottom surfaces roughened in accordance with the principles of the instant invention.

FIG. 2 is a sectional view of a drawing and ironing apparatus which is used to form the blank of FIG. 1 into a seamless container utilizing the method of the instant invention; and

FIG. 3 is a perspective view of a seamless container produced by the apparatus of FIG. 2.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENT

As a preferred or exemplary embodiment of the instant invention, there is provided a circular blank 10 formed of low carbon, cold rolled steel having metallurgical qualities which render it suitable for withstanding the stresses imposed upon it by a drawing and ironing process. An example of a suitable type of steel is one having the following percentage chemical analysis:

- Carbon: 0.05-0.12
- Manganese: 0.25-0.60
- Sulphur: 0.05 maximum
- Phosphorous: 0.02 maximum
- Silicon: 0.10 maximum
- Copper: 0.20 maximum
- Iron: balance

Typical average mechanical properties of such a steel are:

- Ultimate tensile strength: 73,200 p.s.i.
- Yield strength: 70,700 p.s.i.
- Tensile elongation: 13%
- Impact elongation: 67 R 3 T

This steel is of the type known as black plate, and may be chemically treated (either before or after the hereinbefore described sand blasting treatment) to protect it against corrosion, as by being provided with an extremely thin coating of an inorganic chemical composition, as exemplified in U. S. Pat. No. 2,813,812, granted Nov. 19, 1957, or with a flash coating of a metal such as chromium, as exemplified in U. S. Pat. No. 3,113,845 granted Dec. 10, 1963. Plate of the former type is known as CTS (Chemically Treated Steel), while the latter type is generally known as TFS (Tin Free Steel). Heretofore, it has not been possible to draw an iron such types of steel on a commercial basis because its surface condition, even when well covered with lubricating oil, has been such as to cause galling of the ironing dies.

We have discovered that this galling of the dies can be eliminated if the steel is treated, prior to the drawing and ironing operations, by blasting its surface with a hard particulate material such as sand or aluminum oxide in order to roughen them. The blasting operation may be effected by utilizing commercially available air blasting equipment and will be referred to herein as a sand blasting operation regardless of the type of particulate material used. The resultant roughened surfaces 12 contain a great multiplicity of small pits or depressions.

Generally, it is desirable to utilize a fine particulate material in the sand blasting operation in order to increase the density and uniformity of the pits or depressions formed in the surface of the metal sheet. For example, when sand blasting the low carbon, cold rolled steel, it is preferable to use aluminum oxide of 80 grit or finer, and preferably in the order of 80 to 240 grit, or sand in the order of 50 to 100 mesh. Other materials and particulate sizes may be used, depending on various factors such as the properties of the metal being blasted, the characteristics of the drawing and ironing dies, the size and configuration of the article being formed, and the properties of the lubricant to be used during the forming process. By way of example, air blasting low carbon, cold rolled steel with 80 grit aluminum oxide produced a 70 microinch average RMS with a 320 microinch maximum, while a 120 grit aluminum oxide produced a 30 microinch average RMS with a 250 microinch maximum.

The surface roughened blank 10 is operated upon by the apparatus of FIG. 2, the operation and structure of which is covered in our U. S. Pat. No. 3,203,218, granted Nov. 21, 1965. The apparatus comprises a stack of dies, generally designated 14, mounted within a die holder 16. Both the die stack 14 and the die holder 16 are mounted in a suitable press which may be hydraulically or mechanically actuated. The topmost die 18 in the stack 14 is a combined drawing and ironing die formed with a central aperture 20 which has a rounded drawing face 22 at its upper surface and an ironing face 23 immediately therebelow.

A cylindrical forming punch 24 having a flat bottom surface 26 of any suitable configuration is reciprocally mounted above the die 18 in axial alignment with the die aperture 20.

The flat circular blank 10 is inserted between the die 18 and an annular blank holder 28 disposed above the die. The blank holder 28 is formed with a central aperture 30 having an inner diameter slightly greater than the diameter of the punch 24. A spaced series of guide holes 32 extends through the blank holder 28 adjacent its outer edge. Studs 34 having shanks 36 and heads 38 are threadably engaged with the die holder 16 with their shanks 36 extending upwards through the holes 32 in the blank holder 28 to prevent the blank holder 28 from moving transversely relative to the die 18, while permitting it to move to some extent along the longitudinal axis of the die.

The lower surface of the blank holder 28 has formed in it a circular recess 40 of substantially the same diameter as that of the blank 10 and having a depth which is slightly less than the thickness of the blank 10, the recess 40 serving to position the blank in axial alignment with the die aperture 20. When thus positioned, the marginal edge portion 42 of the blank 10 is gripped between the die 18 and the blank holder 28 with a substantial predetermined force due to the action of a plurality of heavy compressed springs 44 which are disposed about the stud shanks 36 and held between the blank holder 28 and the stud heads 38. It will be realized that means (not shown) are provided to raise the blank holder 28 against the pressure of the springs 44 at a suitable time to permit the feeding of the blank 10 into position.

Prior to its insertion into the apparatus of FIG. 2, the blank 10 is coated with a suitable lubricant which fills the depressions on its roughened surfaces 12. Ordinary motor oil slopping into the crevices from S.A.E. 20 to S.A.E. 40 has been found to be satisfactory for the purposes of this invention, but other lubricants may of course be used.

The upper end of the punch 24 is attached to a piston rod 46 which is actuated by a suitable power source such as a hydraulic cylinder (not shown). When actuated, the punch 24 moves...
downwardly, bringing its lower surface 26 into contact with the blank 10. As the downward movement of the punch 24 is continued, the center portion of the blank 10 is forced downwardly to sink the aperture 30 and the marginal edge portion 42 of the blank 10 is progressively forced from beneath the blank holder 28 and into contact with the drawing face 22 and ironing face 23 of the die 18 and is drawn and ironed into a tubular configuration to form a sidewall of a shallow cup.

During this operation, the force with which the marginal edge portion 42 of the blank 10 is gripped between the blank holder 28 and the die 18 is maintained at a level sufficient to insure that the blank 10 is not wrinkled or folded as its marginal edge portion 42 is withdrawn.

As the marginal edge portion 42 is carried through and reshaped by the die 18, at least some of the lubricant which is contained in the depressions on the outside surface of the cup (the undersurface of the blank 10) functions to lubricate the die 18 and to reduce the friction between it and the blank 10. This result is had because the depressions are not ironed out by the die 18, although they are reshaped and made somewhat shallower by it. Thus, the sidewall of the cup which is formed by the die 18, as it leaves the die 18 still has shallow lubricant-containing pockets in its surfaces.

While its upper portion is still engaged by the die 18, the shallow cup enters a second die 48 mounted in the die holder 16 below the first die 18. The second die 48 is an ironing die and has an ironing face 50 which is smaller in diameter than and axially aligned with the ironing face 23 of the die 18. A spacer plate 52 is disposed between the die 18 and the die 48 to produce a predetermined spacing between them. The downward movement of the punch 24 forces the sidewall of the shallow cup face 50, thereby reducing the thickness of and also elongating its sidewall.

During this ironing operation, the lubricant which is present in the still-roughened surfaces of the shallow cup serves to lubricate the die 48 and prevent metal build-up on it. Preferably, the characteristics of the roughened surfaces 12 and the dimensions of the die 48 are such that the small depressions are not completely removed in this ironing operation, and carry some of the lubricant through the die 48 and thus make it available for the next ironing operation, which is effected by a third die 54 which has an ironing face 56 and is mounted in die holder 16 below the ironing die 48 and is suitably spaced therefrom by a spacer 58.

The ironing face 56 is aligned with and has a diameter somewhat smaller than that of the ironing face 50. As the punch 24 continues downwardly, it carries the cup into the ironing face 56, thus effecting a further ironing operation on the side wall of the cup to further reduce its thickness and increase its height and produce a drawn and ironed container or can body 60. As stated, the walls of the cup, as they enter this die 56, still contain remnants of the original depressions, and these contain lubricant which serves to lubricate the die 54. Desirably, these depressions are substantially eliminated, or ironed out, by the die 54, which is the last die in the die stack 14. This elimination of the depressions is desirable to improve the appearance of the finished product, and is possible because there are no subsequent dies which require lubrication. It will be realized that the cup, as it enters the final die 54 in the stack must carry enough lubricant in its surface depressions to lubricate this die and prevent it from galling.

While it has been indicated that the depressions may carry in them a sufficient quantity of the original lubricating oil to provide adequate lubrication for the whole drawing and ironing process, it will be realized that it may be desirable to add additional lubricant to the blanks during the process. This can easily be done by drilling holes in the die holder 16 and spacer rings 52, 58 and using them to inject additional lubricant against the outside surface of the sidewall of the cup as it is forced downwardly by the punch 24.

The drawn and ironed container body 60 (see FIGS. 2 and 3) has a bottom end 62 of substantially the same thickness as that of the blank 10 and a smooth sidewall 64 whose thickness is substantially less than that of the blank 10. It is to be understood that, while the drawings show three dies in the die stack 14, it is suitable merely to illustrate a desired sidewall length and thickness in the body 60. In all cases, it is desirable that the cup, as it enters the final die 54, still have some shallow, lubricant containing depressions in its surface.

After passing through the ironing die 54, the container 60 is stripped from the punch 24 by a conventional stripper, generally designated 66. The stripper 66 consists of a segmented flat annular ring 68 comprising a series of segments 70 adapted to slide radially within a recess 72 in the lower surface of the die holder 16. The segments 70 are urged radially inwardly by springs 74 and are retained within the recess 72 by an annular flat retaining ring 76 secured to the die holder 16 by bolts 78. At the extreme inwardly portion of the segments 70, the segmented ring 68 has a substantially cylindrical inner surface 80 whose diameter is slightly less than the diameter of the punch 24, with a smoothly rounded upper edge 82 and a sharp lower edge 84.

As the formed container 60 is conveyed toward the stripper by the punch 24, it contacts the rounded upper edge 82 of the segmented ring 68, forcing the segments 70 outwards to allow the punch 24 and container 60 to pass through the ring 68. After the container 60 has passed through the ring 68, the springs 74 move the segments 70 inwardly against the punch 24.

The actuating means for the punch 24 then move it upwardly. During the upward movement of the punch 24, the upper rim 86 of the formed container 60 engages the sharp lower edge 84 of the segmented ring 68. This prevents upward movement of the container 60, thereby stripping it from the punch 24. While the rim 86 of the container 60 is shown as being smooth and level, in practice it is usually rather uneven, and a stripping operation is required to produce the smooth rimmed configuration of FIG. 3.

It is apparent from the foregoing description that the roughened surfaces 12 on the interior and exterior side faces of the cup are subjected to different mechanical actions during the drawing and ironing process. The internal side wall surface is forced to undergo a 90° tangential bend during the drawing operation and a tangential force during ironing, whereas the exterior side wall surface undergoes a 90° compressive bend in the drawing and is then exposed to an extrusion or "squeezing" action when passing through the ironing dies.

Because of the different mechanical actions, the exterior surface of the cup undergoes a deformation and change different from that of the interior surface. With each ironing step, the exterior surface undergoes severe deformation as it is squeezed between the particular ironing face and the punch and the oil-containing depressions in the surface become shallower. However, these depressions are not completely eliminated, at least until the final ironing die, and retain a sufficient amount of oil so that during this squeezing the oil that has been retained within the depressions on the surface of the blank provides lubrication for the severe mechanical working and burnishing to which the metal is subjected.

As mentioned hereinbefore, the interior side wall is only forced to undergo a 90° tangential bending in the drawing operation, and so stretching during the ironing operation without being mechanically worked or burnished during ironing. Accordingly, the surface on the interior sidewall may, if desired, be initially roughened to a somewhat lesser degree in terms of the density and depth of depressions than the surface of the exterior sidewall. Alternatively, the roughening of the surface on the interior side wall may be completely dispensed with. However, it is preferred that the interior sidewall have the same degree of roughness as the outside sidewall to retain lubricating oil to reduce the sliding friction between the punch 20 and the interior sidewall of the container during ironing, and to facilitate the stripping operation.
The functioning of the above described apparatus of FIG. 2 in reshaping a flat blank into a cup-shaped container body is described in greater detail in our aforementioned U. S. Pat. No. 3,203,218. While the instant invention has been described as applicable to the apparatus and method of that patent, it will be understood that it is not limited to it, and that it may be utilized in conjunction with other drawing and ironing systems. One such other system does not utilize a combined drawing and ironing die 18 of the type shown in the die stack 14, but instead, as an initial step, forms a shallow cup from the flat blank in a separate cupping press by a drawing operation, and then transfers the cup to an ironing press where a redrawing operation and several ironing operations are carried out.

The roughening of the blank surface as herein described is generally not necessary in a straight drawing operation where the thickness of the sidewall is not substantially reduced, but it is necessary in an ironing operation where galling of the dies, and consequent tearing of the metal of the blank, or of succeeding blanks, occurs if it is not done. Thus, the principles of the instant invention are generally applicable to any metal reforming operation wherein an ironing operation is utilized.

It is thought that the invention and many of its attendant advantages will be understood from the foregoing description and it will be apparent that various changes may be made in the form, construction, and arrangement of the parts and in the steps of the method described and their order of accomplishment without departing from the spirit and scope of the invention or sacrificing all of its material advantages, the form being hereinbefore described being merely a preferred embodiment.

We claim:
1. In the method of forming a seamless container body having a sidewall with a smooth outer surface and a bottom wall of a substantially greater thickness than the sidewall from a thin flat blank by progressively bending concentric annular planar segments of said blank into a cylindrical sidewall to form a cup shaped article in a drawing operation and by thinning and elongating the sidewall of said cup-shaped article in more than one ironing operation to form said seamless container body, the improvement which comprises:
   providing an uncoated low carbon steel blank;
   forming shallow depressions in at least one surface of said uncoated low carbon steel blank, which will form the outer surface of said cup-shaped article, prior to the drawing operation by sand blasting said one surface with finely divided particulate material, selected from the group consisting of aluminum oxide having a particle size within the range of 80 to 240 grit and sand having a particle size within the range of 50 to 100 mesh, which produces a roughness on said one surface within the range of approximately 70 microinch average RMS with a 320 microinch maximum to 30 microinch average RMS with a 250 microinch maximum;
   applying a lubricant to said one surface of said uncoated low carbon steel blank prior to the drawing operation for entrapping lubricant in said depressions; and
   maintaining said depressions at a reduced depth in said outer surface of said cup-shaped article while passing said cup through at least one ironing operation.
2. In the method of forming a seamless container body according to claim 1 wherein said depressions formed in said outer surface of said cup-shaped article are eliminated in the final ironing operation.
3. In the method of forming a seamless container body according to claim 1 wherein said depressions are formed in at least one surface of a web of uncoated low carbon steel, from which said flat blank is cut, by said sand blasting step, said one surface subsequently forming the outer surface of said cup-shaped article.