United States Patent
Shah et al.

[15] **3,655,349**

[45] **Apr. 11, 1972**

[54] **COATED SEAMLESS CONTAINERS AND METHOD OF FORMING**

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[73] Assignee: **Bethlehem Steel Corporation**

[22] Filed: **Sept. 5, 1969**

[21] Appl. No.: **855,475**

[52] **U.S. Cl.** **29/196.4,** 29/196.6, 72/42, 220/64

[51] **Int. Cl.** **B23p 3/20**

[58] **Field of Search** 29/196.4, 196.6; 220/64; 72/41, 42

[56] **References Cited**

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[57] **ABSTRACT**

Sheet steel having differentially coated surfaces of corrosion-resistant metal for use in drawing and ironing seamless articles and the method of forming said articles including coating the opposite surfaces of the sheet steel with metallic coatings having differing lubricity, drawing the coated sheet into a preform and ironing the preform.

10 Claims, 4 Drawing Figures

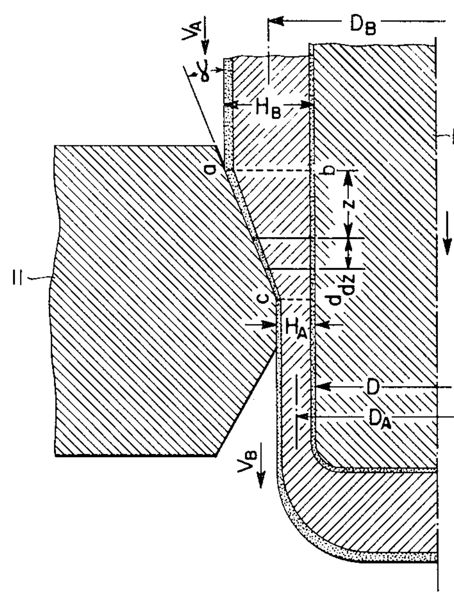


Fig. 1

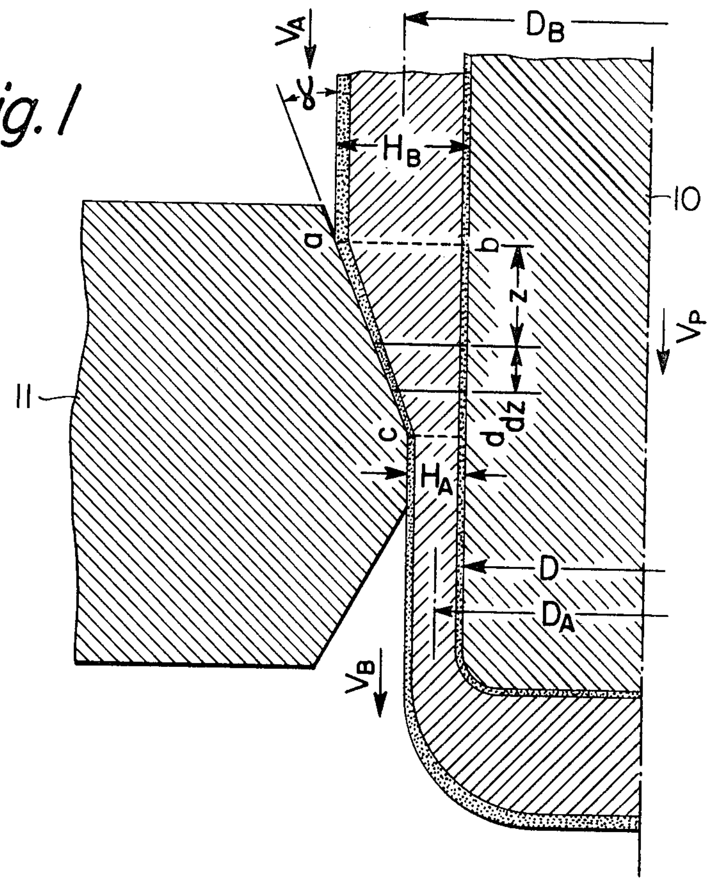
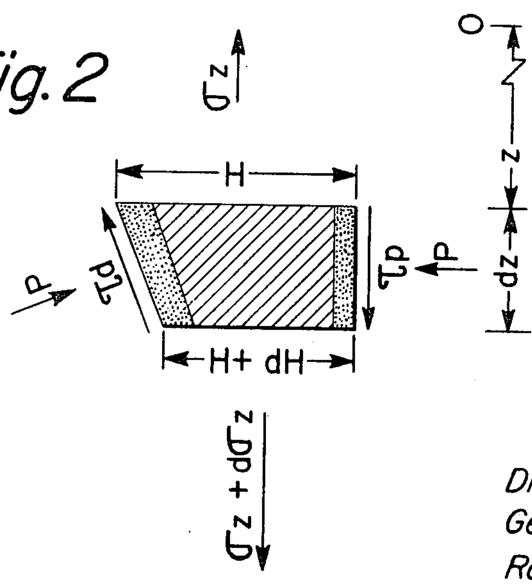


Fig. 2



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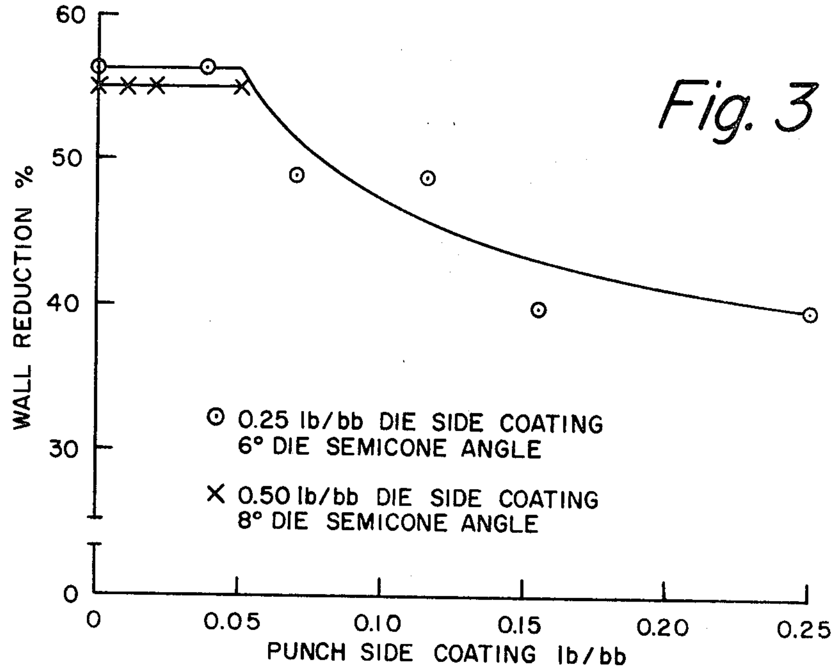

Fig. 3

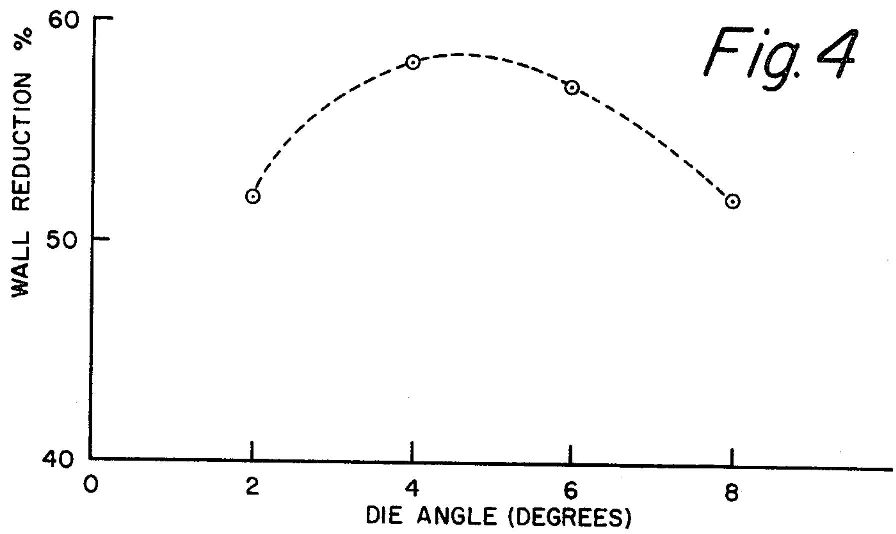

Fig. 4

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COATED SEAMLESS CONTAINERS AND METHOD OF FORMING

BACKGROUND OF THE INVENTION

In the drawing and ironing of thin-walled cylindrical shells, such as seamless steel containers, ways have been sought for producing thin walls with fewer forming steps and with higher production rates. The plastic deformation which occurs in this type of metal working process is limited by two factors: fracture and instability due to changes in frictional conditions both of which will be readily understood by those skilled in the art. These limitations can be largely overcome by the method disclosed herein.

The instant invention provides means to produce drawn and ironed containers using the concept of differential friction to gain large reductions through fewer dies resulting in improved distribution of metal in the container sidewall. The invention further provides blank material having a coating which provides storage rust resistance as well as differential friction in an ironing process.

It is a primary object of this invention to provide a coated steel sheet adapted to achieve maximum wall reduction in ironing through a single die.

It is an additional object of the instant invention to provide a method for drawing and ironing seamless containers from a sheet steel blank having metallic surface coatings of differing lubricity.

A further object is to provide a method for forming thin-walled cylindrical articles which are coated on both sides with a metallic coating.

SUMMARY OF THE INVENTION

The instant invention accomplishes these objects by providing a steel substrate having its surfaces coated with metallic material of different lubricity on opposite sides. The sheet thus coated provides the means for creating differential friction between the punch side and die side of the blank material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial sectional view of the apparatus used in forming articles according to the instant invention;

FIG. **2** is a diagram of the stresses on an element of the article being formed according to the invention;

FIG. **3** is a graphical representation of the effect of differential friction on maximum wall reduction; and

FIG. **4** is a graphical representation showing the effect of die angle on the maximum reduction in wall thickness.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The study of the mechanics of ironing thin-walled cylindrical shells indicates that there are potential advantages if conditions of differential friction are obtained. Specifically, it is apparent can that large ironing reductions can be made in a single die. Experimental development has established practical methods of achieving differential friction in ironing.

A schematic diagram showing the stresses associated with cylindrical shell wall ironing with a moving punch **10** and a stationary die **11** is shown in FIG. **1**. A stationary punch and a moving die will also effectively produce the same state of stress in the deformation zone, although from a practical standpoint the moving punch is more desirable. The radial clearance H_A between the ironing die and the punch is less than the thickness of the incoming material H_B. Therefore, the thickness of the material is reduced as it moves through the die. It can be assumed that the change in the average shell diameter from D_B to D_A as a result of wall ironing is negligible and therefore the circumferential or hoop strain is very small. Thus, it is assumed that the deformation of the material is under plane-strain conditions.

Referring to FIG. **2**, the normal pressure p is assumed to be the same on both the die side and the punch side since the shell wall is very thin. Furthermore, it is assumed that the longitudinal tensile stress, σ and the normal pressure p are principal stresses. This, however, implies that the semicone angle, α, is small. It is also assumed that the longitudinal tensile stress σ is uniformly distributed throughout the wall of the shell. It is apparent that the longitudinal tensile stress, σ dictates the maximum attainable wall reduction. The material enters the die with velocity VA and after ironing leaves the die with velocity VB. An important characteristic of this ironing process is that the punch moves with respect to both the material undergoing deformation and the stationary ironing die. As a result, the velocity VP of the punch at any section of the deformation zone "*abcd*" is greater than the velocity of the material undergoing deformation. After ironing has been completed the material and the punch both move with the same velocity, i.e., $VB = VP$. Thus a relative velocity exists on the punch side, in the material undergoing deformation, opposite to the direction of the punch motion. This induces a frictional shear stress τ between the material and the punch in the direction of the punch movement. As a result, the frictional load due to this shear stress τ aids the ironing process by becoming a negative component of the total ironing load. The frictional load thus relieves some of the tensile stress, σ, in the shell wall which is responsible for fracture. It is pointed out that conversely the frictional shear stress, τ, on the die side of the material acts in a direction opposite to the punch motion. This is due to the fact that material undergoing deformation on the die side is moving in the same direction as the punch motion with respect to the stationary ironing die. Thus, ironing load will have to be supplied to overcome friction on the die side. Greater wall reduction per pass will become possible if the component of the punch load due to the shear stress, τ, increases relative to the component of the punch load due to shear stress, τ.

The reduction attainable in one ironing pass is limited by the tensile strength of the material at the exit side of the die. The maximum reduction will be reached when the tensile wall stress in the shell reaches the value of the material flow stress in plane strain. If the value of the tensile wall stress should exceed the value of material flow stress in plane strain then fracture will occur at the outset of ironing. Die profile and frictional conditions have a significant influence on the maximum wall reduction. When the punch friction is greater than die friction, lower die semicone angles permit larger wall reductions.

Fracture also occurs in an ironing pass after the sidewall has been partially ironed and is evidently due to changes in frictional conditions brought about by deterioration in the lubricating conditions as ironing proceeds. Lubricant breakdown appears to always occur on the outside of the shell. In the ironing process the deformation is more severe on the die side than on the punch side. Further, lubrication failure appears to occur toward the end of an ironing pass. It is reasoned from the above that the coefficient of friction increases as ironing proceeds and the coefficient of friction increases at a greater rate on the die side than on the punch side. Prior art has established that the coefficient of friction increases with increasing wall reduction and this increase is likely to be greater on the die side. Thus it appears that differential friction does not remain constant during an ironing pass and at any given stage in ironing the coefficient of friction on the die side has increased from its initial value more than its counterpart on the punch side. This has the effect of reducing the maximum attainable wall reduction and hence the sidewall fractures after partial ironing. It is also recognized that gradual thickening of the side wall during cup drawing results in increased ironing strain as the ironing proceeds which would also promote the conditions that cause the fracture of the can sidewall as described above.

The sheet steel developed for blanks for use in drawing and ironing of seamless containers by means of the instant invention comprises a steel substrate coated with a corrosion resistant metallic coating on one side having a lubricity no greater than that of the substrate and a corrosion-resistant metallic coating on the other side of higher lubricity. By the term "metallic coating having higher lubricity" is meant a metallic coating having a lubricity substantially greater than that of the steel substrate. Generally speaking, the lubricity of a solid film or thin metallic coating is a function of its shear strength and thickness. Among metallic coatings having a higher lubricity than that of steel are coatings of tin, zinc, copper, and others. Coatings having lubricity no greater than that of the base substrate and coatings of higher lubricity may consist of coatings of the same metal applied in different thicknesses to the steel substrate or may consist of different metals. Experiments were conducted using various ductile, corrosion-resistant, metallic coatings such as brass, zinc, copper, tin, chrome-chromium oxide and others. Much of the experimental work was concentrated on in coatings because of the wide acceptance of this type coating for food and beverage containers.

It is well known to coat both sides of a sheet with equal coating weights to attain corrosion-resistance on both sides and also to prepare the surfaces for enameling. However, as indicated in Table 1 equal weights of tin as, e.g., 0.50 lb./bb on both sides, resulted in allowable wall reduction of only about 36 percent. The instant invention provides a method for attaining reductions in excess of 50 percent.

The effect of tin coating thickness on wall reductions was studied by coating blackplate blanks on one side only with coating weights of tin of 0.10, 0.25, 0.50, 0.75, 1.00, 1.35 and 1.80 lb./bb. The blanks were then drawn and ironed into cylindrical shells by conventional means with the uncoated blackplate surface on the punch side. A soap-base lubricant was circulated in the press to attain the required lubricity during the ironing operation. An effective lubricant film in a plastic metalworking operation has two important qualities, (1) it provides a film of low shear strength to reduce friction and (2) it prevents galling during the forming operation. As stated earlier, tin provides a coating of low shear strength which greatly aids the critical lubrication requirement in the ironing process. A clean tin coating requires some sort of lubrication during ironing to effectively prevent galling. The soap-base lubricant used in our experiments with tin and other metallic coatings contained as much as 95 percent water and was able to prevent galling during ironing. It also helped dissipate the heat build-up in the tooling as a result of plastic deformation. The results tabulated in Table 1 indicate that a wall reduction of as much as 62 percent is attainable. It is noted that increasing the coating thickness above 1.00 lb./bb did not result in any further increase in the maximum wall reduction.

In view of the inadequate corrosion resistance of a blackplate surface, experiments were carried out to establish how much tin coating could be allowed on the punch side of a sheet, for improved corrosion resistance, without significantly changing the differential friction conditions during ironing. Several blackplate blanks were differentially tin coated with 0.25 lb./bb and 0.50 lb./bb tin coating on one side and varying amounts of tin coating on the other side as seen in Table 1 and FIG. 3. The blanks were then drawn into shallow cup preforms and ironed through a single ironing die by conventional means with the lighter coated surface on the punch side. Tin coating weights up to about 0.05 lb./bb on the punch side of the blank did not appreciably change the differential friction conditions during ironing and thus substantially the same wall reductions were achieved with the 0.25 lb./bb and 0.50 lb./bb samples having differential tin coating weights.

Further tests of differential tin coating weights as shown in Table 1 indicate that favorable reductions are available regardless of the thickness of coating as long as the differential lubricity from die side to punch side is substantial. The ultimate application of the container will dictate the amount of coating to be used realizing that an economic factor may also be involved.

The effect of metallic coatings other than tin including zinc, copper, and nickel are shown in Table 1 also. The results indicate that the effects of different coating weights obtained with these other metal coatings were similar to those obtained with tin. It is further noted that where the coating weights were the same on both sides of the sheet, regardless of type of coating, the reduction through a single ironing die was substantially less than in the tests with different coating weights die side/punch side.

In addition experiments were conducted using blanks coated one side with 0.50 lb./bb tin and the other side with chromium. The chromium coating comprised a very thin, i.e. 0.4 μ in., chromium coating, and because of the inherent discontinuity of this thin coating a coating of chrome oxide was added to insure a continuous corrosion-resistant surface. The chromium-chrome oxide surface was applied to the punch side of the blank and as expected the results of the tests matched those obtained in differential tin coating. It is reasonable to expect that application of a chromium-chrome oxide coating in combination with other metallic coatings, as e.g., copper, zinc, and nickel, would yield similar results.

The theoretical analysis of differential friction in ironing thin-walled cylindrical shells indicated that lower die angles would give greater maximum wall reductions. With lower die angles, the area over which the frictional shear stress at the punch-material interface acts, increases and thus the contribution of the friction load toward the total ironing load increases. This has the effect of decreasing the tensile wall stress responsible for fracture of the sidewall.

The effect of die angle on the maximum wall reduction under differential friction conditions is shown in FIG. 4. Differential friction conditions were achieved by applying 0.50 lb./bb of tin coating to only one side of the blank. The results show that the maximum wall reduction increases as the die angle is reduced from 8° to 4°. However, as the die angle decreases, the radial, elastic expansion of the die increases. This is attributed to higher normal pressures at lower die angles. Thus, it was found that a 2° semicone angle die suffered excessive radial expansion and as a result the maximum attainable wall reduction fell below that obtained with a 4° semicone angle die. It must be pointed out that the limitations imposed on the maximum attainable wall reduction when 2° semicone angle die is used, are due to increasing radial expansion of the die and not due to fracture of the sidewall. However, with a semicone angle greater than 2°, the maximum attainable wall reduction is limited by fracture of the sidewall. Our results in FIG. 4 indicate that a 4°–6° die semicone angle α would be optimum. This is true whether the surface of the die entrance is a straight taper as pictured in FIG. 1 or the surface of the die is curved in which case the entrance angle is the slope of the chord of the arc between the point of contact 'a' of the shell material entering the ironing die **11** and the point 'c' where the straight land portion of the die meets the arc at the discharge opening of the die.

TABLE 1.—EFFECT OF VARIOUS PARAMETERS ON MAXIMUM ATTAINABLE WALL REDUCTIONS IN IRONING

Type of coating	Coating weight (lb./bb) Die side of blank	Punch side of blank	Die semicone angle, deg.	Press	Wall thickness before ironing, in.	Wall thickness after ironing, in.	Percentage wall reduction
Tin coating	0.50	0.50	6	Bliss [1]	0.0107	0.0068	36
Tin coating thickness	0.10	None	6	do	0.0107	0.0046	57
	0.25	None	6	do	0.0107	0.0046	57
	0.50	None	6	do	0.0107	0.0046	57

TABLE 1.—EFFECT OF VARIOUS PARAMETERS ON MAXIMUM ATTAINABLE WALL REDUCTIONS IN IRONING—continued

Type of coating	Coating weight (lb./bb)		Die semicone angle, deg.	Press	Wall thickness before ironing, in.	Wall thickness after ironing, in.	Percentage wall reduction
	Die side of blank	Punch side of blank					
	0.75	None	6	---do-----	0.0107	0.0046	57
	1.00	None	6	---do-----	0.0107	0.0041	[4] 62
	1.35	None	6	---do-----	0.0107	0.0041	62
	1.80	None	6	---do-----	0.0107	0.0041	62
Differential tin coating	0.50	None	8	Swift [2]	0.0100	0.0045	55
	0.50	0.01	8	---do-----	0.0100	0.0045	55
	0.50	0.02	8	---do-----	0.0100	0.0045	55
	0.50	0.05	8	---do-----	0.0100	0.0045	[4] 55
	0.25	0.00	6	---do-----	0.0003	0.0045	56
	0.25	0.038	6	---do-----	0.0103	0.0045	56
	0.25	0.07	6	---do-----	0.0103	0.0053	49
	0.25	0.116	6	---do-----	0.0103	0.0053	49
	0.25	0.155	6	---do-----	0.0103	0.0062	40
	0.25	0.25	6	---do-----	0.0103	0.0062	40
	0.10	0.05	6	---do-----	0.0107	0.0045	57
Tin/chrome coating	0.50	0.4u in.	6	Bliss	0.0107	0.0046	57
Zinc coating	0.25	None	6	---do-----	0.0107	0.0052	51
	0.25	0.02,	6	---do-----	0.0107	0.0052	51
	0.25	0.25	6	---do-----	0.0107	0.0065	39
Copper coating	0.25	None	6	---do-----	0.0107	0.0052	51
	0.25	0.02	6	---do-----	0.0107	0.0052	51
	0.25	0.25	6	---do-----	0.0107	0.0065	39
Nickel coating [3]	0.25	None	6	---do-----	0.0107	0.0057	47
	0.25	0.02	6	---do-----	0.0107	0.0057	47
	0.25	0.25	6	---do-----	0.0107	0.0065	39
Tin coating effect of die profile	0.50	None	8	---do-----	0.0107	0.0051	52
	0.50	None	6	---do-----	0.0107	0.0046	57
	0.50	None	4	---do-----	0.0107	0.0045	58
	0.50	None	2	---do-----	0.0107	0.0051	52

[1] In Bliss Press, redrawing and ironing operations are done in the same stroke and the maximum punch speed is about 100 f.p.m.

[2] In Swift Press, redrawing ahd ironing operations are done separately. The punch speed during ironing is about 100 f.p.m.

[3] Nickel coated cans showed light scoring.

[4] Only partial success.

NOTE.—The figures above are representative of approximately 10 specimens for each combination of coating weights shown.

It is evident that the method described herein for forming coated seamless containers from sheet steel blanks with a metallic coating on one side of the blank having a lubricity no greater than that of the substrate and a metallic coating on the other side of higher lubricity is both practical and economical. The method has the advantage of requiring fewer forming steps by ironing through a single ironing die resulting in a shorter press stroke and therefore potentially higher production rates. Another very significant advantage is that with this process the flange area of the container can be left substantially thicker than the main container body and it appears that the reduced work-hardening of the flange area achieved by this procedure will eliminate the incidence of flange-cracking.

This method can be applied to the drawing and ironing of any seamless thin-walled substantially cylindrical article having the desired combination of coatings providing the coating weight differential from the die side to the punch side is substantial and/or the coating on the punch side has a lubricity no greater than that of the base substrate and the coating on the die side has substantially greater lubricity than that of the base substrate.

We claim:

1. Sheet product comprising a steel substrate coated with a metallic coating on one side having a thickness to provide a lubricity no greater than that of the substrate and a metallic coating on the other side having a greater thickness to provide a lubricity which is higher than the lubricity of said metallic coating on said one side.

2. Sheet product according to claim 1 wherein at least one of the metallic coatings is corrosion-resistant.

3. Sheet product according to claim 1 wherein the metallic coating on one side is tin having a thickness of less than 0.05 lb/bb and the metallic coating on the other side is tin having a thickness of 0.10 lb/bb to 0.75 lb/bb.

4. Sheet product according to claim 1 wherein the metallic coating on said one side is chromium-chrome oxide and the metallic coating on said other side is tin.

5. A drawn and ironed seamless thin-walled metal article wherein the metal comprises a steel substrate with a metallic coating on the inside having a thickness to provide a lubricity no greater than that of the substrate and a metallic coating on the outside having a greater thickness to provide a lubricity which is higher than the lubricity of said metallic coating on the inside.

6. A seamless article as described in claim 5 wherein said metallic coating on the inside is chromium-chrome oxide.

7. A seamless article as described in claim 5 wherein said metallic coating on the outside is tin.

8. A seamless metal container as described in claim 5 wherein the metal comprises a steel substrate coated with chromium-chrome oxide on the inside surface and tin on the outside surface.

9. Sheet product with a metallic coating on one side having a thickness less than 0.05 lb/bb and a metallic coating on the other side having a greater thickness to provide a lubricity which is higher than the lubricity of said metallic coating on said one side.

10. Sheet product comprising a steel substrate coated with a metallic coating on one side having a thickness less than 0.05 lb/bb and coated on the other side with a metallic coating having a thickness of 0.10 lb/bb to 0.75 lb/bb.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,655,349 Dated April 11, 1972

Inventor(s) Dipak C. Shah; George W. Ward; Roger L. Whiteley

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 56, delete "can" first occurrence

Column 2, line 1, "σ" should be --σ_z--.

Column 2, line 4, "σ" should be --σ_z--.

Column 2, line 5, "σ" should be --σ_z--.

Column 2, line 18, "τ" should be --τ_p--.

Column 2, line 20, "τ" should be --τ_p--.

Column 2, line 22, "σ" should be --σ_z--.

Column 2, line 24, "τ" should be --τ_d--.

Column 2, line 32, "τ" should be --τ_p--.

Column 2, line 34, "τ" should be --τ_d--.

Column 3, line 15, "in" should be --tin--.

Column 6, line 9, in column "Wall thickness" "0.003" should read --0.0103--.

Signed and sealed this 19th day of September 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents