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PREPARATION OF METAL FOR DEFORMING OPERATIONS

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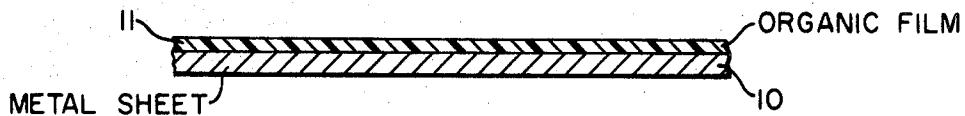


Fig. 1

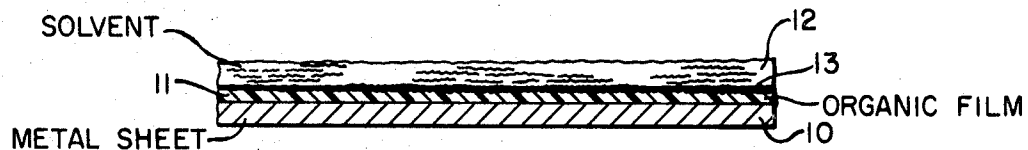


Fig. 2

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PREPARATION OF METAL FOR DEFORMING OPERATIONS

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ABSTRACT OF THE DISCLOSURE

There is provided an improved process and system for the lubrication of the interface between a metal deforming tool and metal being deformed as by cold working, and characterized by a two-coat system including an organic film adhered to a metallic surface and an overlay coating containing a solvent or softening agent capable of developing at the interface between the overlay composition and the resin a mobile system of the resin in the solvent or softening agent.

This application is a continuation-in-part of our co-pending application Ser. No. 453,756, filed May 6, 1965, now abandoned.

This invention relates, as indicated, to a method for preparing a metal surface for deformation, such as by cold working of sheet metal.

One problem peculiar to the handling of metallic workpieces is the contradictory and diverse surface characteristics desired or required in different stages of operation or handling of the metal. At a rolling mill where metal stock is shaped and prepared for shipping to a fabricator, for example, in coils in the case of sheet metal or strip, it is customary to coat the metal with an oleaginous material to minimize oxidation and other forms of corrosion. Obviously, this imparts a low frictional, relatively slippery surface condition to the metal.

Although such oleaginous materials achieve their purpose of protecting the metal, their presence is a disadvantage to the fabricator at the time of further processing the metal. Normally, the fabricator carries out a series of preliminary handling operations to straighten the sheet metal or otherwise preform it for a major deforming step. As an instance, the fabricator may pass sheet metal through an uncoiling machine wherein the sheet metal engages pinch rolls that thrust it forward through straightening rolls and still other roll elements to maintain the tension in the sheet metal, until it finally arrives at a press which, by conventional die action, cuts the sheet stock into blanks. In timed sequence with the blanking operation, the strip or sheet pauses momentarily, so that its forward movement is "stop and go." After each stop, roll action feeds the metal strip to a die in an exact, predetermined or gauged amount. This feed must, therefore, be extremely accurate.

If the driving or feeding rolls tend to slip for lack of friction, there is an immediate malfunction in the entire system. If the metal surface is slippery because of a protective oil coating, the sheet metal is most likely not to have the necessary surface friction. The desired straightening or moving operation is then carried out only with difficulty and inaccuracy.

The kind and extent of lubrication provided at the interface between a metal surface and a die member also plays an important role in the nature of the deformation which takes place. If lubrication of the interface be-

tween the metal being deformed and the die surface is too good, then too much metal is moved relative to the die surface and too little stretching of the metal secured. On the other hand, where it is desired to move large amounts of metal relative to the die/metal interface, then a higher degree of lubrication is desired. Where the article being formed is of symmetrical shape, and the dies are relatively uncomplicated, the kind and nature of the lubrication is a relatively easy problem. However, where the die is unsymmetrical and differential movement of metal is thereby encountered in a given operation, then lubrication to accommodate relatively large movement of metal may be satisfactory in certain portions of the die, and unsatisfactory in those portions where it is not desired to move or displace substantial amounts of metal. Lubrication to accommodate the latter type of metal movement may be quite suitable in certain portions of the die, and quite unsatisfactory in other portions where large amounts of metal must be moved.

Accordingly, it is desirable to provide a lubricating system which overcomes the indicated problems, and especially one which is self-regulating in the sense that it accommodates itself to the conditions imposed at the die/metal interface. It has now been found that a most advantageous lubricating system can be provided by means of a thin resinous coating or film applied to the metal surface and preferably strongly adhered thereto.

This film protects the workpiece against marring, rusting, etc., during handling and storage and yet has a suitable coefficient of friction to enable preliminary processing operations to be performed on the workpiece without slippage. For instance, the film has a high enough coefficient of friction for the coated metal in sheet or strip form to be fed without slippage by a positive roll drive, as in an uncoiling machine and through attendant processing machinery to a blanking die. During this time no additional coating or covering of any character is required on the metal.

Thereafter, an overlay coating of a liquid composition containing a solvent or plasticizer for the resin provides under the conditions of the metal-deforming operation a lubricating system which is self-accommodating to the conditions imposed at the die/metal interface. By following the procedures of the present invention, a resin/softened resin interface is interposed between the confronting surfaces of the metal being formed and the die against which it is being worked. The temperature and pressure conditions undergone by the metal being deformed in the various portions of the mold influence the extent of softening of the resin film. Therefore the extent of lubrication is varied in proportion to the amount of metal which must be moved. In those portions of the die where the amount of metal being moved is relatively slight, the extent of softening of the resinous film is also slight. However, in those portions of the mold where the amount of movement of the metal is large, the temperature and pressure conditions locally obtaining result in more extensive softening of the resin film and a higher degree of lubrication which permits movement of the larger amounts of metal across the die surface. It is this type of differential lubrication, possible with the lubricating systems of the present invention, which primarily distinguishes the present invention from lubricating systems heretofore employed for these purposes.

FIG. 1 is a diagrammatic, sectional view through a metal sheet having an organic film suitable to protect and assist the metal sheet through preliminary stages of handling and/or storage, and

FIG. 2 is a view similar to FIG. 1 in which a solvent layer has been applied to convert a portion of the organic film to a state of relatively low friction and high lubricity.

In FIGS. 1 and 2, the relative thickness of the metal sheet and overlying layers have been exaggerated for purposes of illustration.

Briefly stated, therefore, the present invention involves the provision of a method and system of lubricating the interface between a die member and metal being formed relative to said die member, which method comprises the steps of forming a thin film of plastic adherent resinous coating on at least one surface of the metal at a distribution level in the range of from about 1 to about 10 grams of dry resinous film per square meter and drying the coating. This step in itself enables the provision of a protective film on sheet metal, for example, which may be applied at the mill. Thereafter, this coating is softened to a depth which is less than the thickness of the film to provide a resin/softened-resin interface adjacent the metal/resin interface, such softening being effected under the conditions of forming the metal and without loosening the film from the metallic workpiece. To accomplish the solvation or plasticization, it is preferred that an overcoat of a carrier containing a solvent or plasticizer for the resinous film be applied. Under the conditions of metal deformation, the extent of softening of the film will be dependent upon the pressure and temperature conditions locally obtaining at various points on the metal/die confronting surfaces. The less the amount of movement of metal required, the lower the temperature elevation and thus the lower the extent of softening of the film and the lower the extent of lubrication. In those regions where substantial metal movement is required, the working causes substantial elevation of the temperature, a higher extent of softening of the resinous film, and hence a higher extent of lubrication which permits the greater movement of metal.

Thus, according to the invention, the initially applied organic film protects the metal stock against rusting, corrosion, and marring prior to subjecting it to a metal working operation; it then permits the coated stock to be driven by frictional rolls through preliminary treating machines, blankers, and the like without slippage of the driving rolls; and then, after having a softening agent applied thereto, it becomes an effective lubricant for reducing the sliding friction between the workpiece and the deforming tools. Further advantages of the system include long tool life, non-interference with a subsequent welding operation, reduction of tool marking, and ease in handling the workpiece both before and after deformation.

The desired result of differential lubrication may be obtained with myriad resin-resin activator compositions as will become readily apparent to those skilled in the art. Any resin or resin composition which will form a dry adherent solid film on the surface of the metal, and which can be softened with a "resin activator" in accordance herewith may be used to achieve the objectives of this invention. The "resin activators" of the present invention contemplate any solvent material or combination of materials which is capable, under the conditions of metal deformation, of softening the film to at least some degree. Thus, resin-resin activator compositions or couples useful herein will become readily apparent to those skilled in the art. For an illustrative example, where polystyrene is used as the resinous film for coating the sheet metal prior to deformation, the "resin activator" may be monomeric vinyl toluene dissolved to the extent of from 1% to 20% by weight in mineral oil. The polystyrene may be applied as a resinous composition in the form of a lacquer and the solvent removed by evaporation. This provides a dry, protective coating. The thickness of this coating should be in the neighborhood of .01 to 1 mil thick. The overcoating composition containing the resin activator may be applied just prior to deformation, for example by spray application. This material does not dry and, under the conditions of metal deformation, acts to soften the polystyrene film to develop within the film a resin/

softened-resin interface which is a mobile system providing the lubrication required.

In many instances, it is desirable to ultimately remove the lubricating systems from the surface of the metal in order to prepare the metal for subsequent treatment, e.g. painting or electro deposition. In such cases, it is desired that the composition of the resin be such that it is readily removed with a common solvent such as water or alkali, or an aqueous solution of a common cleansing agent such as sodium polyphosphate. The lubricating systems of the present invention are of such varied nature that they may be designed so as to readily accommodate the foregoing terminal operation.

If the protective film is permitted to remain, as it may be, it will be found not to interfere with welding operations because it is so thin, i.e. less than 1 mil, and usually less than 0.5 mil.

Among the film-forming resinous materials which may be used in accordance with this invention are the following: commercial varnishes; commercial lacquers; alginates, e.g. sodium alginate solution; shellac; zein; gelatin; poly(acrylic acid); poly(acrylic esters); poly(methacrylic acid); poly(methacrylic esters); poly(vinyl acetate); poly(vinyl butyral); poly(vinyl alcohol); poly(vinyl chloride); poly(vinylidene chloride); poly(vinylidene fluoride); poly(vinyl dichloride); poly(vinylpyrrolidone); nitrocellulose; cellulose acetate; cellulose propionate; ethyl cellulose; cellulose acetate butyrate; poly(ethylene); poly(propylene); poly(styrene); allyl alcohol-styrene copolymer; nylon; poly(urethane); coumarone-indene; acetal polymers; diallyl phthalate; phenol-furfural; polyester resins; alkyd resins; silicone-alkyd copolymeric resins.

In addition, material sold under the trade name "Vinsol" may be used to form the organic film. This is a hard, brittle, dark-colored, thermoplastic resin derived from pine wood and containing phenol, aldehyde, and ether groups. The alginates are preferably alkaline salts of alginic acid, such as potassium, sodium, and ammonium alginates. An example of a silicone-alkyd copolymeric resin is Dow Corning's 808 Resin. An example of a poly(acrylic acid) type material is B. F. Goodrich's "Carboset" 525.

The "resin activators" which may be used in accordance with the practice of this invention contemplate, for the most part, solvent materials whose solvent power for the solidified resinous material is preferably higher at elevated temperatures and pressures than it is at ordinary temperatures and pressures. These materials are ordinarily used as single ingredients in a liquid medium such as mineral oil, water, or a hydrocarbon, or some other diluent or nonsolvent for the resinous composition. As indicated above, the amount of such resin activator is generally in the range of from about 1% to about 20% by weight of the overlay composition. It is important to note that, although the carrier for the resin activator may have lubricating properties in its own right, no particular dependence is placed on the lubricity or lubricating properties of the carrier for the resin activator. Thus, mineral oil, which has poor lubricating properties and is notoriously lacking in lubricating properties for metal-deforming operations of the type herein contemplated, provides an excellent carrier for the resin activator. It has a sufficient viscosity and a low enough volatility that it is not readily removed from the surface prior to the deformation operation, and it also has the property of readily wetting and coating the entire surface of the resinous film. The fact that the carrier has any lubricating properties whatsoever is purely incidental and no reliance thereon is made in carrying out the present invention. As a matter of fact, it is desirable that the carrier have minimum lubricating properties since its primary function is to convey the resin activator to the surface for functioning in accordance with the demands imposed by the various die/metal interface portions of the mold. The presence of lubricating properties in the carrier may result in destroying the differential lubricity available in

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these systems and which it is desired to utilize in carrying out this invention.

Among the resin activator materials which may be used in carrying out this invention are the well-known solvent materials such as ketones, alcohols, glycols, esters, ethers, and the like. Because elevated temperatures are encountered in these metal deformation operations, the boiling point of the "resin activator" is desirably above about 150° C.

Similarly, the following liquids, or mixtures thereof where compatible, may comprise the solvent as herein defined: methyl alcohol, ethyl alcohol, propyl alcohol, isopropyl alcohol, butyl alcohol, octyl alcohol, ethylene glycol, propylene glycol, diethylene glycol, poly(ethylene oxides), poly(propylene glycol), benzene, toluene, xylene, methylethylketone, ethyl acetate, isobutyl acetate, dioxane, isophorone, acetone, diacetone alcohol, kerosene, mineral spirits, cellosolve, butylcellosolve, ethylcellosolve, methylcellosolve, cellosolve acetate, cellosolve butylate, dibutyl phthalate, tricresyl phosphate, water, ethyl butyl ketone, cyclohexanone, methyl cyclohexanone, triethanolamine-oleate, and mixtures of the foregoing materials.

As indicated above, the foregoing "resin activators" may be dispersed in various media which, most preferably, are nonsolvents for the resinous material. It is not essential that a diluent be used. For example, if the "resin activator" has sufficiently low softening power with respect to the resinous film, it may be used alone without the aid of a diluent. A material which has this property with respect to a polyacrylic acid film is methylene glycol which may be used at 100% strength. Its effect is one of slow softening at elevated temperatures with respect to this particular material. The following materials or mixtures thereof may comprise a vehicle: mineral oil; vegetable oil, e.g. castor oil, corn oil, soya bean oil, rape seed oil, and palm oil; animal oils and fats, e.g. lard oil, beef tallow, and wool fat; fish oil, e.g., sperm oil; synthetically derived compounds, e.g. methyl oleate, glyceryl monostearate, sorbitan monolaurate, ethylene oxide derivatives of fatty acids, polyoxyalkylene derivatives of sorbitan monooleate, glyceryl trioleate, glyceryl tristearate.

Mineral oil is normally the preferred vehicle or carrier agent because it is economical to use. There are, however, instances in which mineral oil may not be as satisfactory as some of the other vehicles. For example, overlay compositions for sinks, bathtubs, range tops, and other appliance components which are to be porcelainized are preferably made with saponifiable oil vehicles, such as lard oils, tallows, and castor oils. Such saponifiable oils are later readily removed by alkaline baths and assure chemically clean surfaces that are necessary for good adhesion of a subsequently applied porcelain enamel.

To further illustrate the present invention, the following couplets of ingredients for the organic film and solvent have been found to work together satisfactorily:

Resin:	Solvent
Phenol formaldehyde -----	Mineral spirits.
Poly(acrylic acid) resins -----	Methyl ethyl ketone.
Poly(vinyl acetate) -----	Ethyl acetate.
Nitrocellulose -----	Butyl acetate.
Urea-formaldehyde -----	Butanol.
Cellulose acetate -----	Dioxane.
Poly(vinyl butyral) -----	Isopropanol.
Coumarone-indene -----	Mineral spirits.
Polyvinyl resins -----	Isophorone.
Poly(vinyl alcohol) -----	Water.
Silicone-alkyd resin -----	Xylene.

A particularly suitable class of polymers is the poly(acrylic acid) resins comprising poly(acrylic acid) homopolymers, copolymers, and terpolymers. Those materials having high acid numbers, i.e. above 50, and molecular weights in the range of from 100,000 to 200,000 are especially suited for use in accordance with the present invention. They provide excellent adhesion to a variety

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of metal substrates such as carbon steel, stainless steel, aluminum, magnesium, copper, titanium, etc. Coatings formed from this class of materials adhere to the metal during fabrication and evidence little or no spalling. These resins are particularly hard and have a Sward hardness rating above about 25.

In some applications of this invention, the resins are applied to both sides of a metal sheet. Sheets so coated will be stacked or coiled under conditions which will subject the contiguous surfaces to relatively high pressures. Furthermore, during storage and transportation, the coated metal may also encounter elevated temperatures. Under such conditions, the coated surfaces may fuse or stick together and the continuity of the film disrupted when the sheets are taken apart, or the strip uncoiled. Antiblocking agents are desirably incorporated to minimize the occurrence of this problem. Films which show no evidence of blocking when subjected to loadings of 75 p.s.i. at 140° F. for a two-hour period are acceptable. The poly(acrylic acid) resins and homologs thereof are particularly suitable in this respect.

This class of resins also demonstrates desirable properties in respect of flexibility and extensibility. These resins maintain adhesion and film integrity under conditions of sharp bends and metal stretching to 20% of gauge. They are relatively insensitive to moisture, provide good protection against rust and corrosion at high humidity in acidic environments. Inasmuch as the polymer coatings of this invention are designed to be used as temporary coatings, they are desirably removable in conventional alkaline cleaner systems. The poly(acrylic acid) resins which are soluble in relatively mild alkali such as sodium metasilicate, tri-sodium phosphate and sodium carbonate are most practical. Those polymers of the poly(acrylic acid) family having an acid number of 70 or more are particularly suited because of their ready solubility in mild alkali.

Particularly suitable polymers having the properties above described include homopolymers of acrylic acid, methacrylic acid, and ethacrylic acid; copolymers of acrylic acid and methacrylic acid or ethacrylic acid wherein the weight ratio of the co-monomers is in the range of from 1:100 to 100:1, for example 25:75 and 75:25, respectively; and terpolymers of two of the previously mentioned acids with copolymerizable monomers such as maleic anhydride, itaconic, styrene, cyclopentadiene, acrylamide, acrylonitrile, methylacrylate, ethylacrylate, and methylmethacrylate, etc. These monomers may be polymerized in a wide variety of ratios, and for most purposes, the acid monomers are in the large preponderance in these compositions. For example, a suitable terpolymer may be formed from 80 parts of acrylic acid, 17 parts of methacrylic acid and 3 parts of acrylamide. The acrylamide may be replaced with acrylonitrile.

Resinous compositions of this type are well known, and reference may be had to Pats. Nos. 1,933,052, 1,981,102, and 2,160,054, the disclosures of which are incorporated herein by reference, for other specific examples of poly(acrylic acid) type resins useful herein.

Particularly suitable poly(acrylic acid) polymers are commercially available as 30% ammoniacal solutions, or as a 50% solids solution in ethyl acetate, or in granular form as a white solid.

To improve the block resistance and hardness, it is desirable to physically combine the poly(acrylic acid) resin with a high melting point, high acid number resin such as a styrene-maleic anhydride copolymer. Also, to improve the water resistance of the organic film applied to the metal surface, a metallic stearate may be included, although this is not an essential component. Zinc stearate, calcium stearate, cadmium stearate, magnesium stearate, barium stearate, etc., may be used for this purpose. Block resistance is still further improved by the inclusion of a very small amount, for example 2% or less, of a high melting point wax, e.g. carnauba.

Generally speaking, particularly suitable organic polymer film compositions are prepared according to the following formulation:

	Parts
Poly(acrylic acid) resin (acid value >50) -----	75-100
High melting, high acid number resin -----	0-25
Metallic stearate -----	0-5
High melting point wax -----	0-2
Solvent -----	250-1000

Typical examples of film-forming compositions employing the preferred poly(acrylic acids) includes the following:

EXAMPLE 1

	Parts
Polymerized (acrylic acid/methacrylic acid/acrylamide) -----	9
Styrene/maleic anhydride copolymer -----	3
Methylene chloride -----	88

The foregoing formulation provides a rapid drying solvent formulation which is especially useful in a continuous coating and metal forming line.

EXAMPLE 2

	Parts
Poly(acrylic acid) homopolymer -----	18
Styrene/maleic anhydride copolymer -----	2
Zinc stearate -----	1
Carnauba wax -----	0.5
Solvent composition (diacetone alcohol, butyl alcohol, butyl acetate, monoethyl ether of ethylene glycol) -----	78.95

The foregoing formulation provides a solvent type formulation particularly useful in custom coating paint lines. It is particularly used for coating one side of highly finished stainless steel or aluminum. The coated metal is characterized by excellent water resistance and good anti-blocking properties.

EXAMPLE 3

	Parts
Poly(acrylic acid/methacrylic acid, 80:20) -----	20
Styrene/maleic anhydride copolymer -----	3
Calcium stearate -----	.5
Zinc stearate -----	.5
Water -----	76
Ammonium hydroxide to dissolve resin.	

The foregoing formulation is an aqueous ammoniacal solution suitable for mill application to hot rolled steel.

With the foregoing preferred examples of protective organic films, an overlay composition is utilized which, either by chemical or physical means, interacts with the solid organic film in a controllable degree to produce a composite interface of excellent lubricating qualities while retaining outstanding film strength at the resin/metal interface.

The overlay composition particularly suitable for use with the preferred poly(acrylic acid) polymers of this invention may be single or multi-component compositions which at best possess only marginal lubricity under the conditions of metal formation or deformation. The presence of the overlay coating on the polymer coated sheet does not interfere with slitting, blanking, or roller leveling operations that otherwise might be difficult to perform if the overlay coating were of itself a good lubricant.

The following are specific examples of overlay compositions which are useful with any of the foregoing specific examples of poly(acrylic acid) resin formulations:

EXAMPLE 4

	Parts
Mineral oil, 100 SUS at 100° F. -----	90
Butyl Cellosolve -----	10

EXAMPLE 5

	Parts
Lard oil -----	90
Butyl Cellosolve -----	10

EXAMPLE 6

	Parts
Mineral oil, 100 SUS at 100° F. -----	70
Butyl alcohol -----	30

EXAMPLE 7

	Parts
Ethylene glycol -----	100

EXAMPLE 8

	Parts
Water -----	95
Triethanolamine oleate -----	5

Examples 4 and 5 are illustrative of an oil vehicle to which has been added a primary solvent for the polymer film. This solvent may be replaced in part or in whole by any of the solvent materials previously listed. In general, almost any medium hydrogen-bond solvent having a solubility parameter between 8.3 and 14.7 may be used. The mineral oil and saponifiable oil vehicles should not exceed about 200 SUS at 100° F. because problems may be encountered during blanking operations. Concentration of the primary solvent may vary over a range of from 2 to 30% by weight.

Example 6 above is illustrative of a mineral oil vehicle to which has been added a partial solvent and reactant for the poly(acrylic acid) resinous film. In order to provide significant chemical interaction with the polymer film, a much higher concentration of the "resin activator" is used. The butyl alcohol may be replaced in whole or in part with other aliphatic or cycloaliphatic alcohols, e.g. cyclohexanol, capryl alcohol, etc.

Example 7 utilizes a typically high hydrogen-bonded solvent which swells the polymer. Example 8 is an alkaline reacting soap type solution which will soften the polymer film.

The overlay compositions need not be liquid at ordinary temperatures, and may be solids, for example, such as the poly(ethylene glycols) which vary from soft waxy solids to hard waxes.

For most practical purposes, an overlay composition in accordance with Example 5 will be found most suitable for the majority of applications.

It becomes convenient at this point to give illustrative examples of resinous film-forming compositions and overlay coatings which may be used in conjunction therewith, it being understood that these specific examples are for illustrative purposes only and are not to be construed as limiting the scope of the invention thereto.

Techniques of coating a metallic surface with a thin organic film including electrophoretic deposition, deposition of polymerizable materials and formation of a polymer film in situ, etc., are well known in the art and, therefore, are not here described in detail. Normally, an inert liquid carrier transfers a sufficient quantity of the organic film-former to the metal surface, after which the liquid carrier is removed as by evaporation, and the organic material is solidified as a film on the surface. This may be accomplished by heating if the material is thermosetting, or by cooling if it is thermoplastic. If desired, the film-forming material may be applied as a hot melt in the absence of any carrier. Application in any case may be by any of the known methods, such as dipping, spraying, roller coating, doctor-knife coating, etc.

FIG. 1 illustrates a metal sheet 10 to which a layer 11 of organic material has been bonded as described. A sufficient amount of the organic material should be used to cover the metal to a depth such that the film may subsequently be softened as described without affecting the bond of the film to the metal. In general, the thickness of

the film 11 should not exceed 0.3 mil and preferably should be in the range of about 0.05 mil to about 0.15 mil. This corresponds approximately to film weights of from about 100 to about 400 milligrams per square foot. The use of thicker films is not recommended because of possible loss of adhesion.

Certain resins may be preferred for specific applications. For example, if the organic film is to be ultimately removed by an alkali bath after the major deforming operation, resins having an acid number preferably in excess of 70 comprise the organic film. On the other hand, epoxy or poly (vinylchloride) films are desirable if corrosion protection is especially important. Phenol-formaldehyde coatings are generally sensitive to mineral spirits and may be selected because of economic considerations. High temperature resistant coatings are afforded by the silicones which are particularly of interest in hot forming of metals such as magnesium and aluminum. Poly(vinyl acetate) can be applied from a latex and may be preferred for this reason, from an application point of view.

At any desired time after the organic film has dried or otherwise set to a hard condition, the solvent and overlay vehicle indicated at 12 in FIG. 2 is applied over the film 11. A sufficient quantity of overlay composition is used to wet at least that area of the organic film on which the brunt of the deforming action will be exerted and to dissolve or plasticize at least the surface of the film co-extensively with that area, but not through the entire film thickness. In the preferred practice of the invention, reliance is placed primarily on the solvent for the softening effect, and it is, therefore, present in predetermined amount. For example, the vehicle may contain from about 2% to 20% by weight of the solvent or plasticizer for the organic film and preferably from about 4% to 10%. Although the vehicles are often commonly regarded as "lubricants" by themselves, under the conditions of metal forming as by cold working, the lubricity of the carrier or vehicle is of no concern, or in many cases, of no practical lubricating value as previously mentioned. The ability of the carrier or vehicle under these conditions to carry the solvent in a predetermined amount to the resin surface governs its selection in the overlay compositions.

It is emphasized that the introduction of a solvent into a vehicle like mineral oil would normally be expected to detract from its lubricity. However, in this instance the solvent-mineral oil combination has been found to soften the resin film, producing by this action a multi-phase lubricating composition. That portion of the film 11 still in contact with the metal surface remains hard and adherent and serves as a mechanical barrier or boundary layer effective in preventing metallic seizure between dies and the workpiece during deforming. Within the proportions above stated, the "lubricating agent" or vehicle serves as a carrier for the solvent and moderates its activity. Optimum results can then be realized with specific overlay compositions that exhibit a controlled and limited softening of the organic film.

Due to the presence of the solvent or "resin activator" and/or vehicle, the contacted portion of the film 11 softens. As indicated, this may be by a solvation, plasticization, or other like operation that converts the outer surface portion of the film 11 to a soft, semi-fluid state. An interfacial, friction-reducing layer 13 results, and it is this relatively soft and slippery layer which contributes to the unexpected reductions in surface temperature and coefficient of sliding friction of the workpiece in a subsequent deforming operation. The action of the lubricating medium, as represented by the layer 13, may be controlled by limiting the extent of the softening as may be specifically required for a given deforming operation.

In practice, the thin organic film may be conveniently applied at the mill where the metal stock is manufactured, thereby eliminating the customary use of a mill oil to protect the metal against corrosion while in transit or storage.

The oil-free metal is easier to handle and reduces house-keeping problems, both at the mill and at the plant of the fabricator. The fabricator may, at his own discretion, apply the activated overlay composition, (that is, the solvent vehicle composition of the invention) at the flex rolls of a straightening machine or between the flex rolls and a blanker press in a blanking line, or at the metal deforming press or press line. It is entirely practical to use the activated overlay composition hereof at the flex rolls without the necessity of precleaning and thereby eliminate the additional application of a drawing lubricant at the metal deforming press or press line. After being formed, fabricated parts may be stored or subassemblies thereof may be completed, even where welding is required, without any precleaning for removal of the residual and normally still adherent organic film.

The use of a solid organic barrier film is additionally advantageous because it minimizes the problems which arise due to variations in surface finish (roughness) of the metal. Tool life is extended and press performance is more reliable. Since the metal is subjected to less strain in the forming operations, it is possible in some cases to down-grade the class of metal used in forming the desired part.

The combination of an organic film and activated overlay composition of the present invention has been successfully used to replace soap-borax type films. The latter films are most commonly applied in custom coating shops at a premium. The use of low viscosity oil type overlay compositions to soften or plasticize the organic film is also advantageous on automated press lines, because these compositions will not interfere with the operation of microswitches that control the movement of components within the press line.

After the major deforming operation has been completed on the workpiece, the coating-solvent vehicle composite presents no removal problem. Simple systems such as aqueous alkali and acid phosphate cleaners can be used to remove such composites whenever desired after the metal deforming operation. Cleaning is desirable prior to painting or otherwise applying a final surface finish to fabricated articles or parts.

EXAMPLE 9

A pressure cylinder for compressed gas is formed from 0.130 inch blank of hot rolled steel using a conventional soap-borax film as a lubricant. Surface temperature measurements are made on the formed parts as they leave the draw press. It is observed that the critical areas of these parts are raised to a temperature of 180° F. during the metal forming operation. For comparison purposes, a .2 mil film of Vinsol resin is applied to identical test blanks by dip coating from a 10% resin solution in methanol. The blanks are allowed to air dry for at least ten minutes prior to fabrication. An overlay composition consisting essentially of 75% mineral oil and 25% of xylene is then applied to the air dried resin coat. The use of this combination of resin and overlay in accordance with the present invention as a replacement for the soap-borax decreases the temperature of the identical areas to 150° F. Furthermore, rejects are reduced from 2% when using soap-borax to 0.5% when using the present invention, and the cylinders are free of die marks.

EXAMPLE 10

In another test, an engine oil pan is deep drawn from a 0.050 inch cold roll steel while using, of necessity, a heavily pigmented emulsified drawing lubricant. The fabricated pans have to be promptly washed because, on aging, the residual compound becomes progressively more difficult to remove, and also because the residual film interferes with intermediate welding operations.

When the same oil pan is fabricated by first applying a thin film of orange shellac to the blank and then an overlay composition of 75% mineral oil and 25% isopropyl

alcohol, it is possible to omit the washing cycle, and welding can be carried out without any trouble. Furthermore, the quality of the stamping exceeds all previous standards.

EXAMPLE 11

The qualitative appraisals of Examples 1 and 2 can be demonstrated in a quantitative manner by conducting sliding friction tests under conditions simulating those found during deep drawing. For this evaluation the following organic film formers are examined: Vinsol (a hard, brittle, dark-colored, thermoplastic resin derived from pine wood and containing phenol, aldehyde and ether groups); Acryloid (an aqueous solution of poly[acrylic resin]); Elvacet (a water emulsion of poly[vinyl acetate]); orange shellac; and zein. These resins are separately applied to steel test strips, and the resin coatings are dried.

Table A presents values for the sliding coefficient of friction for the steel test strips coated and dried as described and drawn between a pair of steel blocks under the indicated test conditions.

TABLE A

Film-former:	Coefficient of friction
Vinsol	0.48
Acryloid B66	0.30
Elvacet 1440	0.30
Orange Shellac	0.24
Zein	0.18
Vehicle	None used.
Film thickness	0.1 mil.
Load	1,000 p.s.i.
Temperature	72° F.

The addition of mineral oil and solvent as described above significantly reduces the coefficient of friction and is evident in data presented in Table B. Both xylene and isopropyl alcohol exert a solvent effect on the foregoing test resins and thereby reduce the friction. In this particular instance, mineral oil has no solvent effect on the resins employed, and mineral oil alone, therefore, does not reduce the coefficient of friction below 0.20 as when xylene or isopropyl alcohol was present as the solvent.

TABLE B

Resin	Coefficient of friction		
	100% mineral oil ¹	75% mineral oil, ¹ 25% xylene	75% mineral oil, ¹ 25% isopropyl alcohol
Vinsol	>0.20	² 0.12	0.05
Acryloid B66	>0.20	0.10	0.08
Elvacet 1440	>0.20	0.09	0.02
Orange shellac	>0.20	0.10	³ 0.05
Zein	>0.20	0.10	0.12

¹ Mineral oil—Viscosity 100 SUS at 100° F.;

Load—3,500 lbs. per sq. inch;

Temperature—180° F.;

Film thickness—0.1 mil.

² Resin-overlay composition combination for Example 9.

³ Resin-overlay composition combination for Example 10.

EXAMPLE 12

The following procedure is used in the preparation of an enameled iron workpiece. A coating composition is applied to the bare iron workpiece consisting essentially of:

Component:	Weight, percent
Maleic rosin ester having an acid number of 110 (Amberol 750)	15.0
Aqueous ammonia (26%)	2.5
Water	82.5

The coating composition is applied by roller coating the workpiece, although spraying, dipping, etc., could be employed as well. For convenience and in view of time considerations, the coated metal is passed through a drying oven to accelerate removal of the water and the volatile ammonia, although satisfactory film properties can be obtained by simple air drying of the coated workpiece.

The film so deposited has a thickness in the range of 0.1 to 0.25 mil.

The precoated metal is then treated with an overlay composition containing:

Component:	Weight, percent
Lard oil	75-95
Isopropyl alcohol (98%)	5-25

The higher percentage of alcohol provides optimum reduction of friction. The lower alcohol content is preferred when scoring of the metal is a problem. In the latter case, the resin film retains its hardness and provides a better mechanical barrier against metal to metal contact.

After the iron workpiece has been treated as indicated, it is shaped to a desired form in a drawing operation, after which the resin coat and any remaining overlay composition are removed by washing the workpiece in an alkaline bath. Thereafter, enameling frit is applied to the shaped workpiece and an enamel coat produced by techniques known in the art.

EXAMPLE 13

The carrier or vehicle for the solvent need not be an oil. A metal sheet clad with a polyvinyl resin is fabricated into instrument panels with the aid of a vehicle consisting essentially of an aqueous soap solution containing 15% vegetable oil soap and 85% water. The average scrap amounts to 3%. The addition of 20% butyl Cellosolve to the soap vehicle reduces the scrap to 0.2%. Conventional drawing lubricants can be used as vehicles for compounding of the active overlay compositions. The only restriction on choice is one of mutual compatibility of the vehicles and the resin solvents.

While the foregoing discloses several embodiments of the present invention, it is understood that the invention may be practiced in still other forms within the scope of the following claims.

What is claimed is:

1. A process of preparing a metallic workpiece for a subsequent deforming operation comprising the steps of adhering to a surface of said workpiece a solid organic film that is relatively tough and resistant to displacement to protect said surface of the workpiece prior to deforming it, and then, prior to said deforming operation, applying to an exposed surface of the organic film a softening agent effective to convert a surface portion of the film to at least a semi-fluid state of increased lubricity without destroying the adherence of the film to the metallic surface, and while said surface portion is in a semi-fluid state deforming said workpiece, thereby lubricating the workpiece during said deforming operation.

2. The process of claim 1 wherein said organic film is selected from the group consisting of alginates, shellac, zein, gelatin, poly(acrylic acid), polyacrylic esters, poly(methacrylic acid), polymethacrylic esters, poly(vinyl acetate), poly(vinyl butyral), poly(vinyl alcohol), poly(vinyl chloride), poly(vinylidene chloride), poly(vinylidene fluoride), poly(vinyl dichloride), poly(vinylpyrrolidone), nitrocellulose, cellulose acetate, cellulose propionate, ethyl cellulose, cellulose acetate butyrate, poly(ethylene), poly(propylene), poly(styrene), allyl alcohol-styrene copolymer, nylon, poly(urethane), poly(chlorotri-fluoroethylene), coumarone-indene, acetal polymers, diallyl phthalate, phenol-furfural, polyester resins, alkyd resins, and silicone-alkyd copolymeric resins.

3. A process in accordance with claim 2 in which the solid organic film comprises poly(acrylic acid).

4. A process in accordance with claim 2 in which the solid organic film comprises poly(acrylic acid) and the organic film softening agent is a ketone.

5. A process in accordance with claim 2 in which the softening agent is distributed uniformly through a vehicle which is a nonsolvent for the solid organic film.

6. A process in accordance with claim 5 in which the vehicle is mineral oil.

7. A process in accordance with claim 5 in which the solvent material is the monobutyl ether of ethylene glycol.

8. A process of preparing a metallic workpiece for a subsequent deforming operation comprising the steps of adhering to the surface of said workpiece a solid organic film that is relatively tough and resistant to displacement to protect said surface of said workpiece prior to deforming it, said organic film being cast from a film forming composition having the following formulation:

	Parts
Poly(acrylic acid) resin (acid value >50) ---	75-100
High melting, high acid number resin -----	0-25
Metallic stearate -----	0-5
High melting point wax -----	0-2
Solvent -----	250-1000

drying said film; and then, prior to said deforming operation, applying to an exposed surface of the dried organic film an overlay composition having the following formulation:

	Parts
Mineral oil, 100 SUS at 100° F. -----	about 90
Monobutyl ether of ethylene glycol -----	about 10

effective to convert a surface portion of said organic film to at least a semi-fluid state of lubricity without destroying the adherence of the film to the metallic surface; and while said surface portion is in a semi-fluid state deforming said workpiece thereby lubricating the workpiece during said operation.

9. A process of preparing a metallic workpiece for a subsequent mechanical deforming operation comprising the steps of bonding to a surface of the workpiece a solid, resinous, organic film that is relatively tough and resistant to displacement to protect said surface of the workpiece prior to deforming it, applying to the outer surface of the bonded film a liquid having a partial penetrating and

softening effect thereon effective to convert a surface portion of the film to at least a semi-fluid state to impart increased lubricity thereto, and then subjecting the workpiece to the deforming operation while said surface portions is in a semi-fluid state.

10. A method of conducting a metallic workpiece through a series of preliminary handling operations requiring a frictional contact with the metal and terminating with a mechanical deforming operation, said process comprising the steps of adhering to a surface of the workpiece a solid, relatively hard film of a resinous polymer film that is relatively tough and resistant to displacement under mechanical stress to provide a physical barrier preventing seizure between a deforming die and the metallic workpiece, subjecting the workpiece to said preliminary handling operations wherein such frictional contact is made with the polymer film, and then, prior to said terminal deforming operation, applying to the outer surface of the polymer film a liquid having a partial penetrating and softening effect thereon effective to convert a surface portion of the film to at least a semi-fluid state and form a relatively slippery, friction-reducing outer layer of said film for lubricating the workpiece during said terminal deforming step, and then subjecting the workpiece to the deforming operation while said surface portion is in a semi-fluid state.

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