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DRAWING COMPOUND

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This invention relates to drawing compounds and in particular to drawing compounds capable of functioning as lubricants under extremely high pressures and under conditions of considerable frictional heat such as are found in modern seamless steel tube drawing operations. Although the invention is directed to drawing compounds primarily for use in modern seamless steel tube drawing operations, it is obvious that drawing compounds embodying the invention are usable in other metal configurating operations such as the deep drawing of sheets and the drawing of wire.

In metal configurating operations generally, a drawing compound is inserted between the surface of the metal about to undergo plastic reshaping, hereinafter termed "work piece" and the surface of the configurating device, hereinafter termed the "die." The drawing compound serves to keep the said work piece and die separate and to allow the surface of the work piece to slide with respect to the surface of the die under the pressure applied to accomplish the configurating operation. It is commonly known that the lateral shear in the drawing compound permits the sliding of the die with respect to the work piece or vice versa.

Even smooth-appearing metal surfaces of dies and work pieces are microscopically rough and are covered with numerous minute peaks and valleys. Under relatively low pressures between a die and work piece the peaks, termed "asperities," on the surface of the die approach the asperities on the opposed surface of the work piece so that the area of possible metal-to-metal contact between the die and the work piece is very small. However, under the extremely high pressures existing in certain metal configurating operations such as tube drawing, the contact area between the die and the work piece becomes large inasmuch as the asperities are destroyed. If the asperities can wipe each other chemically clean and free from lubricant, the cleaned spots will weld together and lateral motion between the die and the work piece will cause the weaker asperities to break off at their base, or, sometimes the lateral motion between the die and the work piece causes the pulling out of a goodly chunk of metal surrounding the asperities as the asperities are destroyed. When this occurs, the surface that has lost metal is said to have been "worn" and the surface that has gained the metal is said to have "picked it up." If sufficient asperities weld together when a die and work piece are under heavy pressure, lateral motion between the die and work piece is overcome, and the surfaces of the die and work piece are said to have "siezed." If a section of one surface of siezes to another surface and the balance of the surface continues its lateral motion, the siezed surfaces tear away from the surface in motion causing surface imperfections in the work piece of all degrees of seriousness, and, inasmuch as the die is the stronger material, pick-ups build up on its surface and ruin its usefulness.

There are two types of simple lubrication well known in the prior art, namely, "viscous lubrication" and "boundary lubrication." A complete understanding of viscous and boundary lubrication and lubricants is necessary in distinguishing the instant invention from the prior art. Accordingly, a brief discussion thereof will follow.

Viscous lubrication employing viscous lubricants is adequate in metal configurating operations where the pressures are relatively low and where the surfaces are kept relatively far apart by the viscosity of the fluid interposed between the die and the work piece. The lateral movement of the die with respect to the work piece is permitted by lateral shear in the viscous lubricant. In viscous lubricants the film strength, that is, the ability to keep the metal surfaces of the die and work piece apart, is proportional to the viscosity, and, the rate of lateral motion is inversely proportional to the viscosity; thus, as the viscosity increases, more power is required to produce a given configurating operation at a given rate of lateral motion.

Boundary lubrication and boundary lubricants are employed where the pressures are relatively high and when the viscosity of the lubricant has failed to keep the opposing metal surfaces of the die and work piece apart. Where simple lubricants such as petroleum oils fail because of insufficient viscosity to serve adequately as a viscous lubricant, substances such as fatty oils that have chemically active molecules present are employed as drawing compounds. The said chemically active molecules present in boundary lubricants have an affinity for the metal faces of the die and work piece and attach themselves thereto.

The chemically active molecules in boundary lubricants are called "polar molecules" and, in effective boundary lubricants, the polar group is located in one end of the molecule. The active end of the molecule, that is, the end in which the polar group is located, attaches itself to the metal surface of the die or work piece, leaving the free end of the molecule pointing straight

away. This attachment is called "adsorption," and, when the attachment is vertical, that is normal to the surface of the die or work piece, the adsorption is called "orientated adsorption." The strength of attachment of the polar molecules to a metal surface is quite strong, and the adsorbed molecules which resemble the pile of a rug, form a rigid layer on a metal surface of a die or work piece that is of the nature of a polarized solid substance. The strength of attachment depends upon the nature of the active or polar group of the molecule, and, after the first layer is adsorbed to a metal die or work piece, succeeding layers form either singly into single layers in the case of weakly polar molecules or doubly into double layers in the case of strongly polar molecules; the molecules in each of the layers being oriented vertically with respect to the metal surface. In the single layers, the polar groups point towards the first layer, while in the double layers, the polar groups attach to each other, forming pairs, which orient their free ends up and down. Weakly polar molecules form but few layers, all single layers, while strongly polar molecules form many double layers. The stronger polar the molecules, the more double layers formed.

Lubricants forming such adsorbed layers on metal surfaces are said to possess "oiliness" and the ingredients in lubricants which adsorb to the metal surfaces are called "oiliness agents." If a lubricant possesses oiliness and the pressure forcing the metal surfaces of a die and work piece toward each other overcomes the viscosity of the said lubricant separating them, then, the lubricant is squeezed out and the two adsorbed surfaces contact, at first on the asperities and subsequently in surface-to-surface contact when the asperities are destroyed. However, because of the polar force holding the adsorbed layers to the surfaces of the die and work piece, the two metal surfaces do not actually contact but are merely permitted to come closer together until the pressure applied between the die and work piece dislodges polar molecules and permits local seizure between the die and the work piece; lateral movement of the die relative to the work piece being able to take place by sliding between the adsorbed layers until both primary layers attached to each of the opposed metal surfaces are destroyed by the increasing pressure therebetween and insufficient secondary layers remain to replenish them.

In boundary lubricants, sliding also occurs between successive layers adsorbed on the same surface. The attraction of the polar groups for metal surfaces is very high and the attraction of strong polar groups for each other nowhere near as high as for metal but still quite strong. The attraction of weak polar groups for each other is not enough for mutual attachment and they face the influence of the metal surfaces even through other adsorbed layers. The attraction of the free ends of polar molecules for each other is much weaker than the attraction of the free ends of polar molecules for the polar ends of like polar molecules. This being true, one double layer will slide over another double layer with much greater ease than a single layer will slide over another single layer. Coupled with the fact that the strongly polar molecules form many double layers, it is readily observed why strongly polar molecules provide good boundary lubricants. Another fact which affects the efficiency of the adsorbed layers of molecules of boundary lubricants is the thickness thereof. Since the polar molecules stand on end to form the layers, the longer the molecules the thicker the layers, and the thicker the layer, the more the separation of the metal surfaces to which they have been adsorbed, and, therefore, the more efficient they are as lubricants. Among the commonly available polar substances for boundary lubricants, stearic acid has the longest molecule and is very strongly polar.

In viscous and boundary lubrication, fortification of the lubricants is resorted to when the pressure forcing the face of the die and work piece together exceeds the film strength of the viscous lubricant in viscous lubrication or the strength of the attachment of the adsorbed particles in boundary lubricants. When discrete particles are suspended in a lubricant to form a drawing compound, they serve to mechanically separate the faces of the die and work piece, and such discrete particles are called "film fortifiers." In the prior art, at first the film fortifiers were mineral in nature, for example, graphite and talc. Graphite and talc were selected because of the lubricity of their surfaces by reason of which they are commonly known as "mineral lubricants." However, it has been found that graphite and talc have their disadvantages for use in drawing compounds. Talc is commonly considered too abrasive and when graphite is crushed into the surface of the work piece, it is too difficult to clean off to be of practical use. It has been found that two properties of mineral film fortifiers are of particular value in drawing compounds, namely, the possession of a plate-like crystal structure wherein the plates slide one over the other when a critical pressure upon them is reached, and the ability to adsorb oil on their surfaces. Calcium carbonate became generally used as a film fortifier because it possesses the foregoing attributes, is not as abrasive as talc and is not as hard to clean off a work piece as graphite.

Mineral film fortifiers may be used with non-oily viscous lubricants, however, when calcium carbonate is used with a non-oily viscous lubricant, the crushed film fortifier is difficult to clean off the die surface and the work surface. However, when mineral film fortifiers are used with boundary lubricants which contain an oiliness agent, better results are obtained inasmuch as the film fortifier adsorbs a film of polar molecules which it holds with a strength comparable, in the case of calcium carbonate, to that with which the adsorbed polar layer is held by the metal surface of the work piece or die. In the absence of an adsorbed layer, as in the case of non-oily viscous lubricants, the mineral film fortifier would have a rolling contact with the asperities of the metal surface of the die and work piece, with the consequence that a comparatively rapid reduction in their size and therefore in their value would occur. However, in the presence of an adsorbed layer on the metal surfaces of the die and work piece and on the surface of a mineral film fortifier, as in the case of a fortified boundary lubricant, the adsorbed layers would ride over each other up to the point where the pressure thereon exerted by the die against the work piece exceeds the force of the attachment of the adsorbed layers, at which point conditions would revert back to the effectual absence of an adsorbed layer with a consequent accelerated reduction in the size and use-

fulness of the mineral film fortifier. The only alleviation of this condition is obtained by the employment of a fortifier such as calcium carbonate which has a plate-like crystal structure, wherein the plate-like crystal structure fractures under pressure and the debris therefrom tends to fill up the valleys between the asperities to provide a sliding medium between the surfaces of the die and work piece as the tips of the apserities break down.

Where the pressure between the die and work piece exceeds the pressure resistance of mineral film fortifiers, another type of drawing compound may be used. This is, solid coatings of substances which soften at the temperature of the drawing operation and plastically cohere under the pressure present. These solid coatings behave as viscous liquids and provide viscous lubrication up to the point where their viscosity fails to keep apart the opposing metal surfaces. The film strength of such solid coatings is much greater than that of ordinary lubricants.

Still another variation in drawing compounds found in the prior art is where a substance of high film strength is introduced in discrete form into a lubricant in suspension therein. As the pressure and temperature of the drawing operation rises, the discrete particles first function as a film fortifier, then soften, become plastic and cohere to provide a high film strength viscous lubricant. For example, particles of polymerized substances may be gelated by imbibition of a small amount of swelling liquid, and used as a discrete film fortifier possessing a cushioning action, but such particles, by their very nature, must cohere at a critical pressure and thereafter serve as high strength viscous lubricants, this because any swelling liquid is a potential plasticizer and serves as such under sufficient pressure.

Substances which are solid at ordinary temperatures and pressures and plastically form viscous lubricants at high pressures and temperatures prevailing in a drawing operation, revert back to the solid condition after drawing and are usually difficult to remove from the work piece, and usually do not produce a bright finish on the surface of the work piece. Because of the high viscosity of the high film strength viscous lubricants, the power required for drawing is high inasmuch as the rate of lateral movement or shear is inversely proportional to the viscosity.

With the foregoing in view, it is an object of this invention to provide a drawing compound which possesses a film fortifier that will remain discrete in form at all pressures encountered in metal configurating operations, which possesses a film fortifier that will exert a cushioning effect between the opposing metal surfaces of dies and work pieces, which possesses a film fortifier that is relatively unaffected by temperature, and which possesses a film fortifier that will strongly adsorb oiliness agents.

Another object of the invention is to provide a drawing compound which possesses properties admitting of relatively rapid lateral shear in the lubricant and thereby reducing power consumption in metal configurating operations.

A further object of the invention is to provide a drawing compound which contains sufficient strongly polar oiliness agent so that a supply thereof is always available to attach quickly to any spot on a metal surface laid bare of adsorbed molecules by the severity of a metal configurating operation.

It has been found that when fatty oils such as lard oil, tallow oil, neat's-foot oil, rapeseed oil, corn oil, cottonseed oil and olive oil, preferably animal or vegetable oils of high viscosity, are reacted with sufficient sulfur monochloride and mixed with at least 7% to 30% of free fatty acid, preferably to 14% to 20% of free fatty acid and preferably a solid fatty acid such as stearic acid, to form a drawing compound having a viscosity of not less than 1250 cps. at 100° F., the resultant compound is capable of maintaining positive separation of the work face and the die face under the extremely high pressures at temperatures developed in modern severe tube drawing operations. For example, lard oil reacted with 15% of S_2Cl_2 at a temperature not exceeding 190° F. and mixed with 14% to 20% of fatty acid developed a viscosity of 1970 cps. at 100° F. and formed a drawing compound which withstood pressures as high as 375,000 pounds per square inch in actual service without failure.

Drawing compounds embodying the invention are of a consistency and texture capable of forming at room temperatures a semi-dry continuous adhesive film when coated on a metallic surface and exposed to air, thus providing uniform coverage by any convenient means of application. Also, drawing compounds embodying the invention may be easily emulsified with water and applied to work surfaces, the characteristic adhesive film being formed upon evaporation of the water.

The particular classes of fatty oils preferred react with the vulcanizing agent to produce a product containing a vulcanizate characterized by great stability under severe conditions of temperature and pressure in modern metal configurating operations, whereas, some fatty oils, for example, marine oils such as whale oil, menhaden oil, and the like, do not so tightly bind the vulcanizing agent and, in service, are relatively unstable and release corrosive sulfur and chlorine which would impair the essential functions of the stearic acid in drawing compounds embodying the invention.

The highly polymerized vulcanizate has powerful qualities of adsorption and possesses a strong attraction for the highly polar stearic acid. Inasmuch as the vulcanizate is of a complex acid nature itself, the adsorption of the stearic acid does not tend to solubilize or swell it as would an alkaline substance, but rather, the vulcanizate forms agglomerates which serve as discrete film fortifiers. Inasmuch as the vulcanizate is an artificial rubber, it is obvious that discrete particles thereof will be of a cushioning nature. The behavior of the vulcanizate under heat is known, that is, as the heat increases, it becomes harder because of curing tendencies instead of softening as do the highly viscous lubricants of the prior art. In use, drawing compounds embodying the invention produce a bright finish on drawn tubes which is proof that no plasticization takes place when the drawing compound is subjected to severe pressures and frictional heat found in tube drawing and other metal configurating operations. No upper pressure limit has yet been found for drawing compounds embodying the invention and their use permits extremely high reductions in wall thickness of tubes drawn therewith. It will be observed that the stearic acid serves a double purpose, that is, to act as an oiliness agent, and to agglomerate the vulcanizate and thereby main-

tain the discreteness of the agglomerated particles of vulcanizate in the compound.

Drawing compounds embodying the invention require less power for a given metal drawing or metal configurating operation than do other prior art drawing compounds capable of resisting high pressures. When discussing boundary lubricants, it was stated that polar group was attracted to polar group in forming double layers, and as a result, the free ends of the molecules were on the surfaces of the double layers thereby giving a minimum resistance to one double layer sliding over another double layer. Stearic acid is a highly polar substance and forms double layers of polar molecules, therefore, the free ends of the stearic acid molecules form the surface of the adsorbed layer on each metal face and the surface of the adsorbed layers on the agglomerates of the vulcanizate, and also, the free ends of the stearic acid molecules form the surface of the double layers thereof. It is known that there are about 100 double layers of polar molecules on the die face and on the work face at low pressures, but the number of layers of molecules are assumed to be considerably less at high pressures. Therefore, inasmuch as the vulcanizate in a drawing compound embodying the invention is highly polar and the agglomerates thereof are suspended in stearic acid, the internal resistance to shear is at a minimum, and hence, an extremely effective drawing compound is provided. The molecules of the vulcanizate being discrete serve as film fortifiers which act as minute ball bearings and maintain their effectiveness as the pressure and frictional heat of the metal configurating operation increases.

Present in a drawing compound embodying the invention besides the stearic acid and the vulcanizate is a small proportion of the lard oil or other fatty oil existing in various stages of incomplete vulcanization. This comprises an excellent lubricant of good ordinary film strength per se and does not detract from the value of the compound after the main objects thereof are achieved. The presence of the incompletely vulcanized oil in drawing compounds embodying the instant invention is merely a concession to commercial considerations; it being cheaper to prepare a drawing compound embodying the invention by stopping short of complete vulcanization than to contend with difficulties of getting the vulcanizate back into usable form if the vulcanization is carried too far.

The invention is not to be confused with incompletely or partially vulcanized lard oil or other fatty oil in the form and stage heretofore prepared for admixture with mineral oil to provide a compound for lubrication in metal cutting and machining operations. Such lubricants for metal cutting and machining operations were not vulcanized sufficiently to be of use in metal configurating operations such as deep drawing, wire drawing, tube drawing and the like, the said partially vulcanized fatty oil mixed with mineral oil to provide a lubricant for metal cutting and machining operations did not contain a film fortifier and never contained over a small amount of naturally occurring free fatty acid which was considered an undesirable ingredient, and therefore kept low, and was used for lubricants in metal cutting and machining operations primarily because its sulfur content was chemically available to form sulfide films on the tool and work face, that is, the sulfur therein was intended to be loosely bound instead of being more tightly bound as it is in the compound of the instant invention. The sulfide film provided a sufficiently effective oiliness of a temporary nature suitable in metal cutting and machining operations.

It is contemplated that in preparing compounds embodying the instant invention that the viscosity of the fatty oil may be increased by blowing with air at an elevated temperature prior to reacting the sulfur monochloride therewith. Such a step would reduce the amount of sulfur monochloride required to form the requisite amount of vulcanizate. Also, other money and time saving elements contemplated are the use of accelerating compounds for the vulcanizing process. Such basic organic compounds as amines or other organic compounds containing reactive nitrogen such as pyridine, quinoline and the like may be employed to accelerate the vulcanizing process in manufacturing drawing compounds embodying the instant invention. For example, the use of a fraction of a per cent of such substances as pyridine, quinoline and the like to accelerate the vulcanizing process reduces the amount of sulfur monochloride required and materially speeds up the formation of the vulcanizate.

It is to be understood that any known or later discovered method of vulcanizing may be used in producing the vulcanizate drawing compounds embodying the invention such as free sulfur with heat, hydrogen sulfide, polysulfides, etc., and, any desired method of increasing the viscosity of the fatty oil prior to vulcanization may be used such as blowing with air, voltolizing, and the like.

It is to be understood that the particular compounds and methods disclosed and the procedure set forth are presented herein for the purposes of illustration and explanation only, and that various equivalents can be used and modifications of the composition, method and procedure set forth can be made without departing from the spirit of the invention as defined by the appended claims.

I claim:

1. A drawing compound substantially free from mineral oil comprising an intimate mixture of a higher fatty acid and a product of vulcanization of a high viscosity fatty oil other than marine oils, the said drawing compound being characterized by having the property of forming at room temperatures a semi-solid continuous adhesive film when coated on a metallic surface and exposed to air.

2. A drawing compound substantially free from mineral oil comprising an intimate mixture of a higher fatty acid and a product of vulcanization of a high viscosity fatty oil other than marine oils, wherein the vulcanized oil is stable under heat and pressure developed in severe metal configurating operations, the said drawing compound being characterized by having the property of forming at room temperatures a semi-solid continuous adhesive film when coated on a metallic surface and exposed to air.

3. A drawing compound substantially free from mineral oil comprising an intimate mixture of a product of vulcanization of a fatty oil other than marine oils and 14% to 20% of a higher fatty acid.

4. A drawing compound consisting of an intimate mixture of a product of vulcanization of a fatty oil selected from the class of fatty oils which consists of lard oil, tallow oil, neat's-foot

oil, rapeseed oil, corn oil, cottonseed oil and olive oil, and 14% to 20% of a higher fatty acid.

5. A drawing compound substantially free from mineral oil comprising a product of vulcanization of a high viscosity fatty oil other than marine oils intimately mixed with 14% to 20% of higher fatty acid, the said compound having a minimum viscosity of 1250 cps. at 100° F.

6. A drawing compound consisting of a product of vulcanization of a fatty oil selected from the class of fatty oils which consists of lard oil, tallow oil, neat's-foot oil, rapeseed oil, corn oil, cottonseed oil and olive oil, intimately mixed with 14% to 20% of a higher fatty acid, the said compound having a minimum viscosity of 1250 cps. at 100° F.

7. A drawing compound substantially free from mineral oil comprising a product of vulcanization of a high viscosity fatty oil other than marine oils intimately mixed with 14% to 20% of stearic acid, the compound having a minimum viscosity of 1250 cps. at 100° F.

8. A drawing compound consisting of a product of vulcanization of a fatty oil selected from the class of fatty oils which consists of lard oil, tallow oil, neat's-foot oil, rapeseed oil, corn oil, cottonseed oil and olive oil, intimately mixed with 14% to 20% of stearic acid, the said compound having a minimum viscosity of 1250 cps. at 100° F.

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