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Review Article

Tablet lubricants I. Theory and modes of action

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Tablet lubricants are essential components of all tablet formulations, since they prevent sticking of the tablets in the dies. Without tablet lubricants, tablets cannot be produced. A lubricant may be defined as a suitable material, a small amount of which interposed between two rubbing surfaces will reduce friction arising at the interface (Strickland et al., 1960; Komarek, 1967).

A lubricant should also be capable of reducing wear on the rubbing surfaces (Silversher, 1969). To perform this function the lubricant must provide a film that will prevent solid-to-solid contact, and is easily sheared (Jentgen, 1971). Lubricants are added to tablet formulations primarily to reduce friction between the die wall and granules as the tablet is formed and ejected (Sprowl, 1974; Lachman et al., 1970). The other main activities attributed to a lubricant are: (a) prevention of sticking of granules to the tooling—anti-adherent; and (b) improvement of granule flow properties—glidant (Lachman et al., 1970). A given lubricant may provide one or more of these actions to varying degrees but no one material is highly efficient in all categories (Sperandeo and De Machi, 1976; Strickland, 1959; Sprowl, 1974). Accordingly combinations of lubricants are often selected to provide the necessary total lubricant effect (Maly, 1963; Munzel and Kogi, 1954). Careful selection is necessary since some lubricants may interact adversely when in combinations; for example, magnesium stearate and talc (De Blaey, 1972), although some authors have found that these two lubricants are compatible (Rubio, 1957; Esnaud et al., 1973). Although tablet lubricants have been used in practice for many decades it is only in the last 15 years that the lubrication process has been studied fundamentally.

The lubrication process

When two solids in contact are displaced relative to each other and parallel to the plane of contact, a resistance known as friction must be overcome (Bowden and Tabor, 1958; Bowden and Tabor, 1967). Surfaces are not smooth, but consist of irregularities known as asperities which are large compared to molecular dimensions

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(Fein, 1971). When two surfaces are brought together, they initially "touch" at points on the highest asperities. Application of a load causes deformation of the asperities initially elastically then plastically until the load is supported. It is at this point that the real contact area between the two surfaces is established (Buckley and Johnson, 1972). For tangential motion to occur between the two surfaces, these interfacial junctions must be sheared. This is the welded junction theory of Bowden and Tabor (1958). This theory is applicable to tableting since sliding friction is involved as: (a) granules slide over each other and across the die wall during compression; and (b) the tablet slides across the die wall during ejection. Frictional resistance is interpreted as the shearing of welded junctions formed between points of contact and the ploughing out of the softer material by the harder material riding over it. This can readily be seen in an inadequately lubricated granulation, because the tablets will bear vertical striations along their edges, reflecting the high frictional force of ejection along the die wall (Sprowl, 1974; Lachman, 1970). The total frictional force is given by (Buckley and Johnson, 1972; Bowden and Tabor, 1967):

$$F = SA$$

where F = frictional force; S = shear strength of junction; and A = surface area in contact. The relative value assigned to the friction of contacting surfaces is the coefficient of friction, μ (Silversher, 1969).

$$\mu = \frac{S}{W}$$

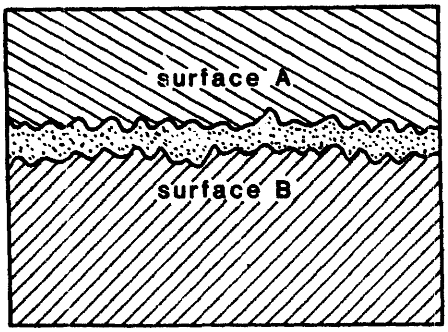
where S = shear strength of junction; and W = yield strength of softer material. The purpose of lubrication therefore, is to reduce S by the prevention of the formation of welded junctions by preventing asperity contact or by lowering the shear strength of the junctions that are formed (Silversher, 1969). Lubrication can thus be achieved by the application of a continuous film of lubricant to the moving surfaces or by boundary films, which do not totally cover the sliding surfaces.

In fluid lubrication the moving surfaces are completely separated by a continuous film of lubricant and the resistance to motion arises solely from the viscosity of the lubricant itself (Fig. 1). Fluid lubrication is not a surface phenomenon. A fluid lubricant has a coefficient of friction of approximately 0.001 and wear is negligible. Boundary lubrication, however, is a surface phenomenon. The sliding surfaces are separated by lubricant films only a few molecules in thickness and therefore the nature of the underlying surface will affect the friction (Bowden and Tabor, 1967). The surface asperities support much of the load (Fig. 2), friction coefficients are much higher, approximately 0.05–0.15, and wearing does occur (Fein, 1971). Boundary lubrication is provided by natural surface films, for example, water vapour, contaminants or low shear strength laminar solids (referred to as solid lubricants; for example, metallic stearates). Since the main function of a boundary lubricant is to interpose between the sliding surfaces, any film that is able to reduce the amount of surface interaction and is itself easily sheared may be termed a boundary lubricant. The lubricant must, however, have a low shear strength, must be able to adhere to the surface to be lubricated and also be tough enough in film form to resist rupture and minimize wear (Carver, 1974; Buckley and Johnson, 1972). Under boundary lubrication the load is supported over an area A (Fig. 3) by the lubricant film and by minute junctions formed where the lubricant film has been penetrated. The frictional force, F, is the sum of the force required to shear the junction and the force to shear the lubricant film.

$$F = aAs + A(1 - a)s_l$$

where s is shear strength of surface, s_l is lubricant shear strength, and a is fraction over which junction formed. For a good boundary lubricant, a is very small so that the major sliding resistance comes from shearing of the lubricant itself, hence the low shear strength requirement (Bowden and Tabor, 1967).

Strickland (1959, 1960) was the first to attempt to correlate general lubrication theories to the behaviour of lubricants in tableting. Hydrocarbons such as mineral oil were stated to be examples of fluid-type lubricants being dependent upon viscosity for their effectiveness. They lubricated the die wall and prevented seizure of the two surfaces in proportion to their ability to maintain the continuous layer



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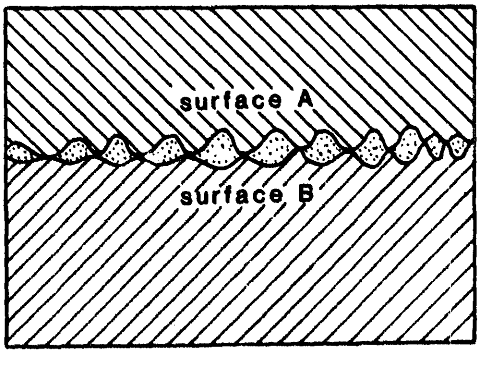
∿ , boundary layer;

▨ , bulk fluid.



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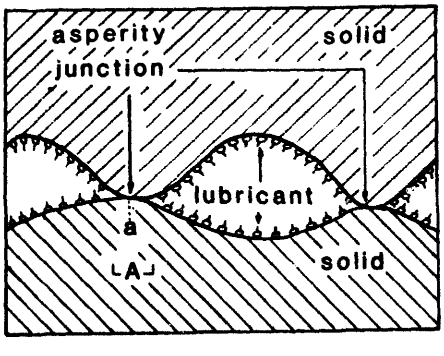

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Fig. 1. Fluid film lubrication of two surfaces.

Fig. 2. Boundary film lubrication of two surfaces.

Fig. 3. Mechanism of boundary lubrication.

between the surfaces. The main problem with fluid lubrication was the increase in tackiness (reduction in the rate of granule flow) and a reduction in tablet strength (Lachman et al., 1970; Salpekar, 1975). Boundary lubrication results from the adherence of polar portions of molecules with long carbon chains to the opposing surfaces, for example, magnesium stearate. The latter type is most commonly used in tableting because it is more effective, requires smaller quantities and is more easily applied to granules (Strickland, 1959). From his study, Strickland (1960) concluded that tablet lubrication appeared to be generally amenable to the theory of lubrication reported for other systems.

Theories and modes of action of lubricants

Based on the Bowden and Tabor theory of friction, the shear strength theory is now the most commonly accepted mechanism of lubrication with respect to tableting. This shear strength theory suggests that the frictional force at the tablet–die wall interface results from the shearing of junctions between the tablet and the wall materials (Lachman et al., 1970). Thus the lubricant is thought to offer a lower shear interface than that characteristic of the die wall–tablet surfaces and will thus readily shear when tangential motion is initiated between the tablet and the die during the ejection process (Strickland, 1959). Shear strength values for various lubricants have been measured by Train and Hersey (1960) using a punch penetration test. Scruton et al. (1972) measured the shear strength of calcium stearate monolayers and multilayers and other materials and concluded that shear strength could not be simply interpreted in terms of molecular structure and orientation, but was perhaps more closely related to bulk rheological properties even though the film may be only one or two molecules thick. This view was supported by Jentgen (1971) who concluded that lubrication for solids cannot be ascribed to any one property of the materials; thermal and oxidative stability, chemical reactivity, mobility, hardness and crystal structure all affecting lubricant function and performance. Use of shear strength measurements to evaluate lubricants has been attempted by Lewis and Shotton (1965) and Lewis and Train (1965), but they found no correlation between lubricity and shear strength.

Boundary films can be chemisorbed (Allen and Drauglis, 1969) and these types of films are most suitable for boundary lubrication because of the strong adherence to the surfaces to be lubricated (Buckley and Johnson, 1972). An example is soap formation (Bowden and Tabor, 1958). Next in order of lubricant ability are physically adsorbed films provided by polar molecules on non-chemically reactive surfaces. Adhesion is not as strong but lateral cohesion is high. Adsorption of non-polar molecules on a metal substrate is usually very weak since adhesive and cohesive forces are small (Allen and Drauglis, 1969). However, the latter has been reported to be more effective than a fatty acid or soap above its melting point (Rabinowicz and Tabor, 1951). Thus metallic soaps are very effective boundary lubricants because they have high melting points and suitable shear properties.

Another mechanism of lubrication has been proposed by Wolff et al. (1947). These workers suggested that a lubricant might act as a conductor of static electricity by providing more points of contact which in turn would reduce the high charge build up during the rapid compression of some compounds. Work by Gold and Palermo (1965a) showed that magnesium stearate and talc reduced the static charges generated by flow of particles through a tablet hopper. The authors carried out a further study on the antistatic properties of the tablet lubricants themselves (Gold and Palermo, 1965b). Magnesium stearate, polyethylene glycol 4000, sodium lauryl sulphate and talc had the ability to lower accumulation of static charge. The antistatic properties decreased with a decrease in lubricant concentration and was independent of the material accumulating the charge. A similar behaviour for magnesium stearate was also reported by Bhatia and Lordi (1979).

Thus, although many theories abound to explain the mechanism of lubricants, including an electron distribution theory of Jamison (1972), no one theory explains completely how a lubricant functions in preventing friction. It would seem that as newer materials are evaluated as lubricants, a clearer picture of their mode of action will evolve.

References

Allen, C.M. and Drauglis, E., Boundary layer lubrication: monolayer and multilayer. Wear 14 (1969) 363–386.

Bowden, F.P. and Tabor, D., In Friction and Lubrication of Solids, Clarendon Press, Oxford, 1958.

Bowden, F.P. and Tabor, D., In Friction and Lubrication, Methuen, London, 1967.

Bhatia, R.P. and Lordi, N.G., Electrical conductance of directly compressible materials under pressure. J. Pharm. Sci., 68 (1979) 222–226.

Buckley, D.H. and Johnson, R.L., Lubrication with solids. Chem. Technol., 2 (1972) 302–310.

Carver, S.E., Roller bearings—II. Lubrication. Lubrication 60 (1974) 61, 62, 70, 71.

De Blaey, C.J., Quantitative determination of the friction during compression in terms of the work involved. Pharm. Weekbl., 107 (1972) 233–242.

Esnaud, J.M., Clerc, J., Tebbi, H., Duchêne, D., Levy, J. and Puisieux, F., Direct compression of pure excipients and excipients in the presence of phenobarbital on a reciprocating machine. Ann. Pharm. Fr., 31 (1973) 103–116.

Fein, R.S., Boundary lubrication. Lubrication 57 (1971) 1–12.

Gold, G. and Palermo, B.T., Hopper flow electrostatics of tableting material. J. Pharm. Sci., 54 (1965a) 310–312.

Gold, G.and Palermo, B.T. Hopper flow electrostatics of tableting material. J. Pharm. Sci., 54 (1965b) 1517–1519.

Jentgen, R.L., Solid lubricants. How they work and where to use them. I.E.E.E. Trans. Parts Hybrids Packag., 7 (1971) 86–93.

Jamison, W.E., Structure and bonding effects on the lubricant properties of crystalline solids. A.S.L.E. Trans., 15 (1972) 296–305.

Komarek, K.R., Selecting binders and lubricants for agglomeration processes. Chem. Eng. 74 (1967) 154–155.

Lachman, L., Lieberman, H.A. and Kanig, J.L., In Theory and Practice of Industrial Pharmacy, Lea and Febiger, New York, 2nd edn., 1970.

Lewis, C.J. and Shotton, E., A comparison of tablet lubricant efficiencies for a sucrose granulation using an instrumented tablet machine. J. Pharm. Pharmacol., 17 (Suppl.) (1965) 825–865.

Lewis, C.J. and Train, D., The compaction of some solid lubricant materials. J. Pharm. Pharmacol., 17 (1965) 577–583.

Maly, J., Mixed lubricants. Tablet studies IV. Pharm. Ind., 25 (1963) 573–578.

Munzel, K. and Kogi, W., The evaluation of lubricants in tablet manufacture. Pharm. Acta. Helv., 29 (1954) 53–71.

Rabinowicz, E. and Tabor, D., Metallic transfer between sliding metals. Proc. Roy. Soc., A208 (1951) 455–475.

Rubio, G.I., Technology of compressed pharmaceutical tablets. Anal. Fac. Quim. Y. Farm. Univ. Chile, 9 (1957) 249–254.

Salpekar, A.M., Some Important Aspects of Tablet Lubrication, Ph.D. Thesis, 1975.

Scruton, B., Tabor, D. and Willis, R.F., Shear strength of lubricant monolayers. Nature (London), 236 (1972) 59–60.

Silversher, H.I., Materials for lubrication applications, NASA Spec. Publ. SP-3051 (1969) 199–239.

Sperandeo, F. and De Marchi, G., The role and mode of action of the lubricant in tablet manufacture. Boll. Chim. Farm. 115 (1976) 801–809.

Sprowl, Sprowl's American Pharmacy, 7th edn. J.B. Lippincott, Philadelphia-Toronto, 1974, pp. 311, 337, 338, 359, 360, 366, 367.

Strickland, W.A., Jr., A new look at tablet lubricants. Drug Cosmet. Ind., 85 (1959) 318.

Strickland, W.A., Jr., Higuchi, T. and Busse, L.W., The physics of tablet compression. J. Am. Pharm. Ass., 49 (1960) 35–40.

Train, D. and Hersey, J.A., The use of laminar lubricants in compaction processes. J. Pharm. Pharmacol., 12 (1960) 97T–104T.

Wolff, J.E., Dekay, H.G. and Jenkins, G.L., Lubricants in compressed tablet manufacture. J. Am. Pharm. Ass., 36 (1947) 407–410.