This invention relates to improved die lubricants useful in forging metals. Forged high stressed metal parts are being used in the construction of aircraft. These parts very often include heavy metal sections joined to thin webs. In attempting to press forge such parts in metal dies great difficulty has been encountered in filling the die cavities in the location of the webs due to the rapid conduction of heat from the billet into the die blocks and consequent chilling of the hot metal before the cavities are filled. This difficulty has been recently solved by electrically heating the forging dies to temperatures as high as 1900° F. and forging the metal parts in the heated dies. By greatly reducing the conduction of heat from the metal to be forged it is possible to form parts with thin sections without difficulty from metals and metal alloys heretofore impossible to satisfactorily press forge in semi-finished form, such as parts made from alloy steels, titanium, beryllium and their alloys. Furthermore it is possible by the use of heated dies to obtain much greater reduction of the stock without requiring reheating due to the lower conduction of heat from the stock to the dies.

The use of heated dies, however, gives rise to difficulty in releasing of the forgings from the dies due to sticking and pressure welding of the forging surfaces to the die blocks causing the surfaces of the die cavities to be damaged and causing surface defects in the forgings.

In solving this problem it was determined that the dies must be coated with a lubricating or parting agent having low heat conducting properties at high temperatures, having good adhering properties, being non-reactive with the die surfaces and having good lubricating and releasing properties to prevent sticking of the forging to the die surfaces. Preliminary tests with materials such as colloidal graphite, zinc oxide, lead oxide, molybdenum disulfide, molybdenum oxide, powdered "Pyrex", glass, glass wool, barium carbonate, powdered zinc oxide and magnesium oxide indicated that high temperature refractory materials would not serve as suitable parting agents, lead and lead oxide formed an adherent film on the heated dies at 1600° to 1800° F. and served as a lubricant but were highly corrosive to the die surfaces at these temperatures. Flake graphite alone was somewhat satisfactory except for the difficulty of coating overhead die surfaces.

In order to test the suitability of various lubricating materials electrically heated dies were made from cast Inconel 713 C alloy with flat polished engaging surfaces. The dies were heated with temperature control in steps from 600° to 2000° F. Cylindrical test pieces of A.S.I. 4340 steel one-half inch in diameter and one-half inch high were heated to 2250° F. and each successively inserted between the dies when the latter were mounted in a hydraulic press and a constant load of 10,500 lbs. applied. Tests were made at die temperatures of 600° F., 800° F., 1000° F., 1200° F., 1400° F., 1600° F., 1800° F. and 2000° F. At each temperature the dies were initially un lubricated and the test piece subjected to load with the maximum reduction in height, the time to forge and the increase in diameter at the portion of the test piece contacting the die faces being carefully noted. As each lubricating or parting agent was tested the dies were coated with the material prior to insertion of the test piece and the load then applied to the test piece. Where no lubricant was applied the reduction in height of the test piece is primarily due to bursting or bulging of the sides with little or no increase in diameter at the point of die contact while good lubrication will allow the stock to expand radially, moving over the die faces, hence the increase in area of the portions of the test piece contacting the die faces compared to the same area increase with no lubrication is a measure of the lubricating qualities of the material under test. The comparative time required to forge at each die temperature is indicative of the lubricating qualities of the parting material as is also the percentage reduction in height.

From the tests on more than sixty individual materials and compositions it was evident that no single material was suitable to meet all of the desirable criteria.

It was found that the only satisfactory composition was a fusible metal salt acting in its molten state as a vehicle for a nonreactive lubricating component. The following alkali metal salts have been found satisfactory: potassium sulfate K₂SO₄, potassium bisulphate KH₂SO₄; potassium bisulphide KH₃S; lithium chloride LiCl; and potassium iodide KI.

The fusible metal salt component may vary from a minimum of about 25% to a maximum of 60% by volume of the lubricating composition and the salt component may be any of the above alone or mixtures thereof. Lithium chloride while satisfactory would probably be ruled out because of expense and potassium sulphate K₂SO₄ is suitable only below die temperatures of 1800° F., since it is highly corrosive to the die surfaces at temperatures of 1900° F. and above. For use with die temperatures from 600° F. to 1300° F, potassium sulphate, potassium bisulphate KH₂SO₄ and mixtures thereof or either mixed in about equal parts by volume with potassium iodide are preferred. For die temperatures ranging from 1300° F. to 1900° F. potassium iodide KI is preferred.

Suitable lubricating components of the composition have been found to be powdered mica, powdered synthetic mica, powdered talc, powdered western bentonite, and powdered flake graphite. The lubricating component of the lubricating composition may be employed singly or mixtures thereof may be used. The total amount in percent by volume of the lubricating component or mixture of such components may vary from about 40% to 75% by volume of the lubricating composition.

Satisfactory formulations with all percentages indicated being percent by volume are as follows:

For use with die temperatures 600° F. to 1600° F.: 25% KHSO₄+25% bentonite+50% flake graphite 25% KI+25% bentonite+50% flake graphite 25% KI+50% bentonite+25% flake graphite 25% KI+37.5% bentonite+37.5% talc 60% KI+20% talc+20% flake graphite 30% KI+30% K₂SO₄+20% bentonite+20% flake graphite 50% LiCl+50% flake graphite 30% LiCl+30% K₂SO₄+20% mica+20% flake graphite 50% KHSO₄+50% bentonite 33% KI+67% flake graphite 50% KI+50% flake graphite

For use with die temperatures 1600° F. to 1800° F.: 50% KI+50% flake graphite 25% KI+50% flake graphite

For use with die temperatures 1900° F. +: 50% KI+50% flake graphite

Since die oxidation is greatly accelerated at tempera-
tures above 1800° F. this is probably the maximum operating temperature. The compositions having the best overall properties for use in the lower die temperature range 600° F. to 1300° F. is:

25% KHSO₄ + 75% bentonite
50% KHSO₄ + 50% bentonite

the latter formulation being preferred.

The formulation usable over the entire practical die temperature range 600° F. to 1900° F. is: 33% KI + 67% flake graphite.

The lubricating compositions in accordance with the invention are finely powdered, for example powdered graphite (120 mesh), potassium iodide (140 mesh) and the powdered ingredients measured by volume and intimately mixed dry. The mixed formulation is applied to the heated die surfaces by spraying the mixed dry powders with a compressed air spray gun with the spray orifices suitably enlarged. The alkali metal salt component melts and tenaciously binds the lubricant component of the mixture to the heated die surfaces.

While it is preferred to spray the lubricating composition in the dry powder form it is understood that the ingredients can be mixed with a light petroleum oil that will evaporate without leaving a carbon residue and applied with a spray gun.

The lubricating composition is applied to the heated dies so that it builds up to a coating of about twenty-thousands of an inch thick, the coating being initially very porous but which is reduced to about one-thousandth of an inch when pressure is applied by the forging press.

I claim:

1. In the art of press forging of metals wherein the dies are electrically heated to temperatures in the range of from 600° F. to 1800° F. independent of the conduction of heat thereto by the heated forging stock, the method of lubricating the heated die cavities: to insure filling thereof, ready release of the forging from the dies and having no deleterious effects on the die surfaces consisting of coating the heated die cavities with a lubricating composition, said lubricating composition consisting of a powdered fusible alkali metal salt non-reactive to the heated die surfaces and selected from the group consisting of potassium sulfate, potassium bisulfate, potassium bisulphide, lithium chloride, potassium iodide and mixtures thereof, and a finely divided lubricant dispersed in said carrier, the lubricant being chemically inert with respect to the carrier and to the heated die surfaces and stable at forging temperatures, the lubricant being carried by the molten carrier into all parts of the dies in contact with the heated forging stock, the lubricant being selected from the group consisting of powdered mica, talc, western bentonite, and flaked graphite, the carrier varying from 25% to about 60% by volume of the lubricating composition.

2. A lubricating composition for lubricating forging dies consisting of an intimate mixture of powdered potassium bisulfate and powdered bentonite, the potassium bisulfate being present in the range of from 25% to 50% by volume of the composition and the balance being bentonite.

3. A lubricating composition for lubricating forging dies consisting of an intimate mixture of powdered potassium iodide and powdered bentonite, the potassium iodide being present in the amount of 25% by volume based on the volume of the mixture from 25% to 50% by volume of bentonite and the balance flake graphite.

4. A lubricating composition for application to press forging dies heated from 600° F. to 1900° F. consisting of an intimate mixture of 33 percent by volume potassium iodide and 67 percent by volume flake graphite.

5. A lubricating composition for application to heated forging dies consisting of an intimate mixture of powdered potassium iodide and powdered flake graphite, the potassium iodide being present in an amount ranging from about 20 percent to 50 percent by volume of the volume of the mixture, the balance being flake graphite.

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