LUBRICANT FORMULATION FOR HIGH TEMPERATURE METAL FORMING PROCESSES

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Abstract
Improved lubricant system useful in metal forming processes. The lubricant formulations contain boron nitride lubricant with graphite additions. These formulations enhance lubricity while maintaining good adherence at elevated temperatures.
FIG. -6-
LUBRICANT FORMULATION FOR HIGH TEMPERATURE METAL FORMING PROCESSES

TECHNICAL FIELD

[0001] The present invention relates generally to lubricant formulations useful for elevated temperature metal forming processes such as quick plastic forming, superplastic forming, and warm forming processes.

BACKGROUND OF THE INVENTION

[0002] Development of lubricants for elevated temperature metal forming processes such as quick plastic forming (QPF), superplastic forming (SPF), or warm forming requires the following features: low coefficient of friction, good adhesion to the blank, uniform application pattern, low cost and ease of removal after forming. Petrochemical based lubricants are ineffective due to the high temperatures utilized in these processes. The most commonly used lubricant for processes involving such elevated temperatures is boron nitride (BN). However, other lubricants such as graphite, molybdenum disulfide, and magnesium hydroxide (commonly referred to as milk of magnesia when in aqueous suspension) have been used.

SUMMARY OF THE INVENTION

[0003] This invention is believed to provide advantages and alternatives over prior practices by providing improved lubricant formulations useful in elevated high temperature metal forming processes. The formulations contain boron nitride lubricant with graphite additions. These formulations enhance lubricity while maintaining good adherence to the surface of the blank.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The accompanying drawings which are incorporated in and which constitute a portion of this specification illustrate an exemplary embodiment of the invention in which, together with the general description above and the detailed description set forth below will serve to explain the principles of the invention wherein;

[0005] FIG. 1 illustrates a cross sectional view of a metal blank and female and male shaping tools prior to metal forming;

[0006] FIG. 2 illustrates a cross sectional view of a metal blank and female and male shaping tools during metal forming;

[0007] FIG. 3 illustrates a cross sectional view of a metal blank and female and male shaping tools upon completion of metal forming;

[0008] FIG. 4 illustrates a cross sectional view of a metal blank and female and male shaping tools after removal of the male tool;

[0009] FIG. 5 illustrates a cross section view of a metal blank and female and male shaping tools after removal of the formed metal blank; and

[0010] FIG. 6 illustrates the effect of graphite to boron nitride ratio on coefficient of friction.

[0011] While embodiments of the invention have been illustrated and generally described above and will hereinafter be described in connection with certain potentially preferred procedures and practices, it is to be understood and appreciated that in no event is the invention to be limited to such embodiments and procedures as may be illustrated and described herein. On the contrary, it is intended that the present invention shall extend to all alternatives and modifications as may embrace the broad principles of the invention within the true spirit and scope thereof.

DETAILED DESCRIPTION

[0012] For ease of reference and understanding, the following description is set forth with respect to a simplified exemplary metal formation process. Importantly, it is to be understood that the lubrication system of the present invention is in no way limited to such a formation process. Rather, it is contemplated and intended that the lubrication system will be broadly applicable to any number of elevated temperature metal formation practices.

[0013] Reference will now be made to the various drawings wherein to the extent possible, like elements are designated by corresponding reference numerals in the various views. FIGS. 1-5 illustrate schematically a simplified exemplary so called “warm forming” practice utilizing male and female formation tool members. In the illustrated practice a female member 12 includes a mold cavity 32, bottom surface 14, and two opposing wall surfaces 16. A metal blank 22 is placed on top of the female member such that a portion of the bottom surface 30 of the metal blank 22 is in direct contact with the outer surface 24 of the female member 12.

[0014] FIG. 1 shows the metal blank 22 in position between female member 12 and a complementary male tool 18 such that the upper surface 28 of the metal blank 22 faces the male tool 18. Means (not shown) can be provided to heat both the male tool 18 and the metal blank 22 to a suitable temperature. The male tool 18 is pressed against the upper surface 28 of the metal blank 22. This operation results in creation of an interface region 40 (FIG. 2) between the male tool 18 and the upper surface 28 of the metal blank 22 and causes deformation of the metal blank 22 to conform to the shape of the mold cavity 32 of the female member 12.

[0015] As shown in FIG. 2, the pressure of the male tool 18 acting on the upper surface 28 of the metal blank 22 deforms the metal blank downwardly toward the bottom surface 14 of the female member 12. The bottom surface 30 of the metal blank 22 engages a portion of the opposing wall surfaces 16 creating an interface region 38 between the female member 12 and the bottom surface 30 of the metal blank 22. In FIG. 3, the male tool 18 has pressed the bottom surface 30 of the metal blank completely against the opposing walls 16 and the bottom 14 of the female member 12. This further deformation creates a continuous interface region 38 between the female member 12 and the metal blank 22 and a continuous interface region 40 between the male tool 18 and the metal blank. At the completion of the forming operation, the male tool 18 is lifted from engagement with the upper surface 28 of the metal blank 22 (FIG. 4) and the metal blank 22 is removed from the female member 12 (FIG. 5).

[0016] As will be appreciated by those of skill in the art, the formation process illustrated and described in FIGS. 1-5 is exemplary only. Any number of other elevated temperature formation processes may also be utilized. By way of example only, and not limitation, various elevated temperature forming processes are disclosed in U.S. Pat. No. 5,819,572 to Krajewski, the contents of which are incorporated herein by reference in their entirety.

[0017] Regardless of the formation practice utilized, some type of lubrication is typically used during metal forming processes. Lubrication is needed to avoid sticking and thereby facilitate deformation of the work piece. Lubrication also serves to assist in the release of the formed part from die
and tool members. The lubricant may be applied to the surface of the work piece undergoing deformation and/or to surfaces of the formation tools.

[0018] The instant invention provides an improved lubrication system utilizing boron nitride (BN) lubricant with graphite additions to enhance lubricity while maintaining good adherence to the metal blank and/or tool members to which it is applied. In one potentially preferred embodiment, addition of at least 5% and more preferably about 5% to about 50% graphite to boron nitride results in improved lubricity (lower coefficient of friction) compared to BN alone. Unlike lubrication formulations which are predominantly graphite, the inventive boron nitride-graphite formulations maintain good adhesion to the metal blank and formation tool surfaces. Other constituents may be present in the lubricant provided they do not materially degrade the features of lubricity and adhesion.

[0019] According to the contemplated practice, the inventive boron nitride-graphite formulations can be sprayed on the metal blank or other work piece using conventional paint spraying techniques and can be removed with standard techniques currently used for pure BN. In a potentially preferred practice, the metal work piece is aluminum or magnesium although other work piece materials may likewise be used. The inventive boron nitride-graphite formulations are believed to be particularly suitable for formation practices carried out at temperatures of about 250 degrees C. or greater.

[0020] The substantial benefits in lubricity achieved as a result of graphite addition are illustrated in FIG. 6. In this chart coefficient of friction (COF) is measured for different levels of graphite addition to boron nitride. Coefficient of friction was measured using a Cameron Plint reciprocating plate on test procedure at 450 degrees C. The test was duplicated at each level of graphite addition to confirm relative performance.

[0021] As shown, standard boron nitride lubricant with no graphite addition (far left columns) yielded substantially greater coefficient of friction levels than samples with graphite addition. The data also show that with the addition of graphite lubricity tends to be maintained at substantially equivalent levels for longer time periods. This is reflected by the fact that there was no substantial increase in coefficient of friction during latter stages of the friction test. Moreover, a visual examination of samples following the friction tests showed that pure graphite (far right columns) tended to delaminate to some degree while the BN graphite combinations maintained substantial adherence. The lubricant blend thus provides the benefit of improved lubricity in combination with long term adhesion under friction.

[0022] It is to be understood that while the present invention has been illustrated and described in relation to potentially preferred embodiments, constructions, and procedures, such embodiments, constructions, and procedures are illustrative only and that the invention is in no event limited thereto. Rather, it is contemplated that modifications and variations embodying the principals of the invention will no doubt occur to those of skill in the art. It is therefore contemplated and intended that the present invention shall extend to all such modifications and variations as may incorporate the broad aspects of the invention within the true spirit and scope thereof.

1. An elevated temperature metal forming process comprising the steps of:
   - heating a metal work piece to a temperature of at least 250 degrees C.;
   - applying a lubricant formulation to at least one of (a) a metal work piece surface and (b) a surface of a formation tool; deforming the metal work piece within the formation tool to substantially conform with the surface of the formation tool; and removing the metal work piece from the formation tool, wherein the lubricant formulation comprises boron nitride in combination with not less than about 5% graphite.

2. The invention according to claim 1 wherein said metal forming process is quick plastic forming.

3. The invention according to claim 1 wherein said metal forming process is superplastic forming.

4. The invention according to claim 1 wherein said metal forming process is warm forming using complementary male and female formation tools.

5. The invention according to claim 1 wherein said metal forming process is an aluminum forming process.

6. The invention according to claim 1 wherein said metal forming process is a magnesium forming process.

7. An elevated temperature metal forming process comprising the steps of:
   - heating a metal work piece to a temperature of at least 250 degrees C.;
   - applying a lubricant formulation to at least one of (a) a metal work piece surface and (b) a surface of a formation tool; deforming the metal work piece within the formation tool to substantially conform with the surface of the formation tool; and removing the metal work piece from the formation tool, wherein the lubricant formulation consists essentially of boron nitride in combination with about 10% to about 50% graphite.

8. The invention according to claim 7, wherein said metal forming process is quick plastic forming.

9. The invention according to claim 7, wherein said metal forming process is superplastic forming.

10. The invention according to claim 7 wherein said metal forming process is warm forming using complementary male and female formation tools.

11. The invention according to claim 7 wherein said metal forming process is an aluminum forming process.

12. The invention according to claim 7 wherein said metal forming process is a magnesium forming process.

13. An elevated temperature metal forming process comprising the steps of:
   - heating a metal work piece to a temperature of at least 250 degrees C.;
   - applying a lubricant formulation to at least one of (a) a metal work piece surface and (b) a surface of a formation tool; deforming the metal work piece within the formation tool to substantially conform with the surface of the formation tool; and removing the metal work piece from the formation tool, wherein the lubricant formulation consists essentially of boron nitride in combination with about 5% to about 33% graphite.

14. The invention according to claim 13, wherein said metal forming process is quick plastic forming.

15. The invention according to claim 13, wherein said metal forming process is superplastic forming.

16. The invention according to claim 13 wherein said metal forming process is warm forming using complementary male and female formation tools.

17. The invention according to claim 13 wherein said metal forming process is an aluminum forming process.

18. The invention according to claim 13, wherein said metal forming process is a magnesium forming process.