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Pryor et al.

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[54] **DIE WITH LUBRICATING SYSTEM FOR THE EXTRUSION OF BILLETS**

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[52] **U.S. Cl.** **184/6;** 425/97; 72/253

[51] **Int. Cl.²** **F16N 1/00**

[58] **Field of Search**........ 184/1 E, 18, 6, 6.21, 6.22; 164/174, 73, 268; 425/461, 97, DIG. 115; 72/253

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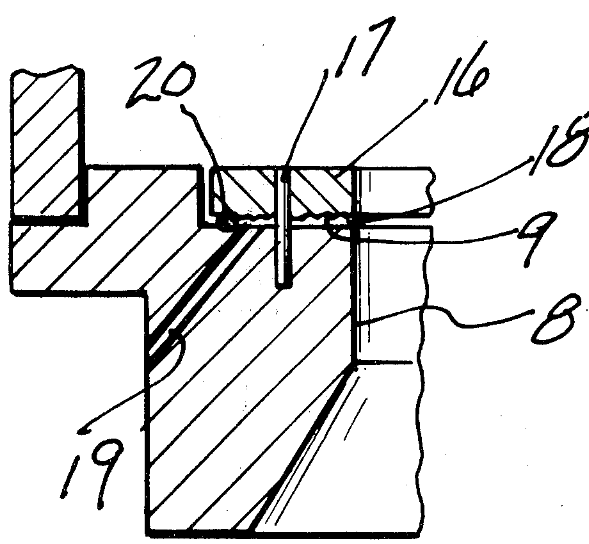
[57] **ABSTRACT**

An extrusion die in a container wherein a plate is recessed in the die and is positioned between a billet to be extruded and the face of the die. On at least one of the adjacent faces of the die and plate there is a knurled surface. The region formed between the plate and the die forms a passageway for lubricant to the extrusion die so that the lubricant may aid in the extrusion of a billet. There is a passageway in the die for the introduction of lubricant to the area between the plate and the die. The knurled surface has 10 to 50 grooves per inch, and the grooves have a depth of 0.0005 to 0.02 inches. A seal may be used to seal the passageway from the interior of the container. The die and plate may be of the same metal. The lubricant conduit in the die may have an enlarged cross-section prior to joining the passageway region between the plate and the die.

6 Claims, 10 Drawing Figures



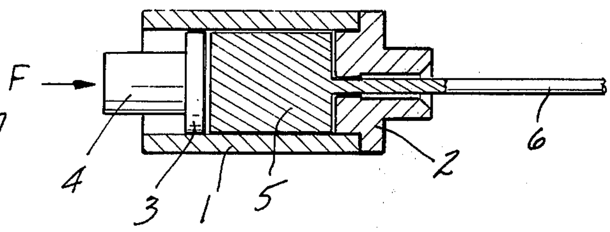


FIG-1

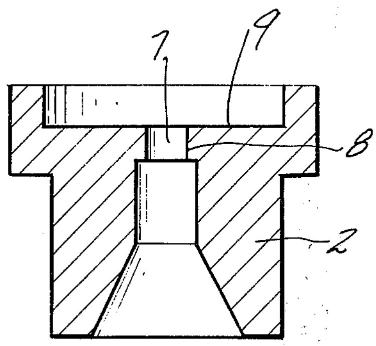


FIG-2

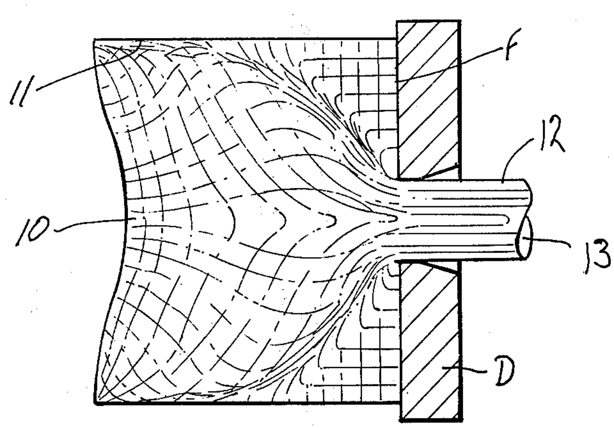


FIG-3

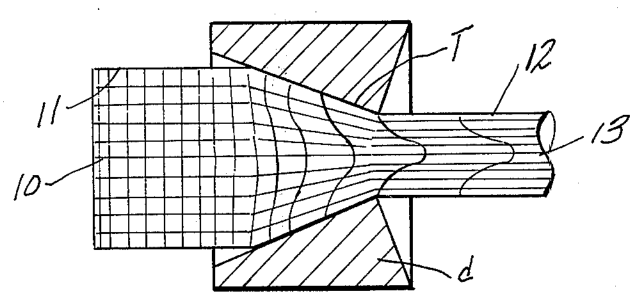


FIG-4

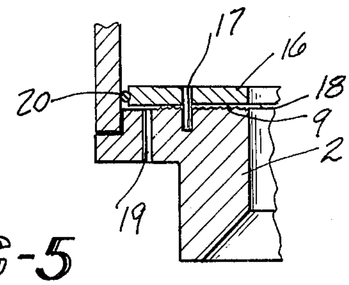


FIG-5

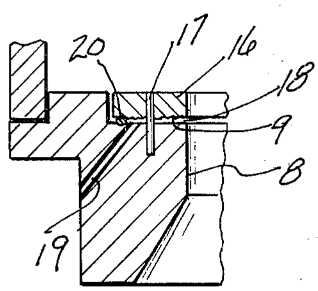


FIG-6

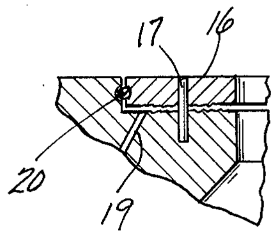


FIG-7A

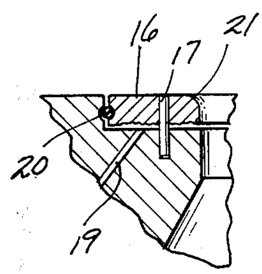


FIG-7B

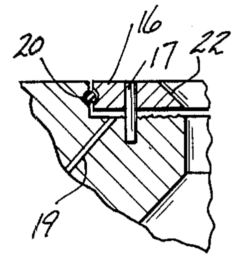


FIG-7C

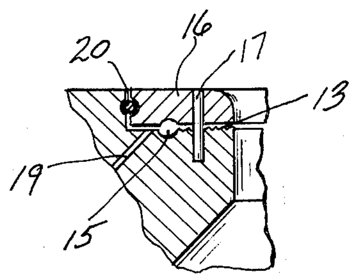


FIG-8

DIE WITH LUBRICATING SYSTEM FOR THE EXTRUSION OF BILLETS

BACKGROUND OF THE INVENTION

Extrusion is a widely used process for shaping aluminum. In the direct extrusion process a billet of aluminum is placed in a cylindrical container, furnished at one end with a die having a wall of the appropriate dimension for the finished product. Dies having a flat face are commonly used. A piston moves into the container from the opposite end under an applied force sufficient to force the aluminum to flow through the shaped opening in the die. Aluminum is usually hot extruded at a temperature above its recrystallization temperature. It is a characteristic of aluminum extrusions, made with flat faces dies, that the material which flows through the die in the early stages of the extrusion process comes from the center of the billet. The surface of the billet which is usually contaminated with aluminum oxide would be the last of the billet to be extruded and generally, the extrusion process is stopped before the surface portion of the billet is extruded. A colloidal graphite mixture is usually sprayed on the die prior to extrusion. This mixture prevents the billet from adhering to the die and reduces the pressure necessary to initiate extrusion, but the graphite is effective as a lubricant for only a small fraction of the material being extruded.

It would be highly desirable to provide a method of continuous lubrication so that the force required for extrusion could be reduced i.e., reduced pressure to initiate and complete the extrusion. This would enable the production of larger extrusions on a given size press. In current practice the friction of the aluminum flowing through the die produces a localized high temperature, particularly when some build up of aluminum has occurred on the surface of the die. This temperature may be sufficient to cause softening of the die and may further cause localized rapid grain growth in the material at the surface of the extruded product. The combination of higher temperatures and aluminum build up on the die leads to tearing and poor surface quality on the extruded product.

Because of the desirability of preserving the conventional metal flow pattern of the billet as it is extruded it is not feasible to introduce lubricant between the wall of the container and the billet surface. The present invention overcomes these difficulties and provides a novel and useful method for lubricating aluminum extrusions.

SUMMARY OF THE INVENTION

An apparatus for lubricating the interface between the die and the billet during hot extrusion is disclosed. The apparatus consists of a metal plate placed within the billet container adjacent to the die. One of the surfaces between the metal plate and the flat die face is knurled and an appropriate lubricant is fed under pressure into this knurled space. The lubricant emerges from the knurled space and coats the interface between the die and the extruded product.

It is an object of the present invention to provide a means for introducing a lubricant between the surfaces of the die and the extruded product in apparatus for hot aluminum extrusion.

Further objects and advantages of the present invention will be made evident as reference is made to the detailed description of the invention and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a schematic cross-section of a typical direct extrusion press.

FIG. 2 shows a cutaway view of an extrusion die similar to that shown in FIG. 1.

FIG. 3 shows a schematic of a flow pattern in the hot extrusion process, using a flat face die.

FIG. 4 shows a metal flow pattern in a lubricated type extrusion process, using a die having a tapered face.

FIG. 5 shows an embodiment the apparatus of the present invention.

FIG. 6 shows a preferred embodiment of the apparatus of the present invention.

FIG. 7 shows a variety of shapes for the plate of the present invention. FIGS. 7A, 7B, 7C show a metal plate 16 with different edge configurations, square, round, and tapered, respectively.

FIG. 8 shows a preferred embodiment which provides a more uniform coating of lubricant.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The apparatus of the present invention are adapted for use with conventional direct extrusion presses used for the high temperature direct extrusion of aluminum and aluminum alloys with flat faced dies. Such a press is shown schematically in FIG. 1. The press consists of a hollow cylindrical container 1 having at one end an appropriately configured die 2 and at the other end a movable piston 3. The piston moves in response to the movement of a ram 4 which in turn has a force F imparted to it usually through some hydraulic means. The billet 5 to be extruded is placed within the container 1 and as the piston 3 moves into the container 1 the billet is forced through the opening in the die and the extruded product 6 assumes the general shape of the die opening.

FIG. 2 shows a view of the cross-section of a typical flat faced aluminum extrusion die. The die 2 has an opening 7 which is defined by the walls of the die 8. The flat face of the die 9 is in contact with the billet to be extruded. This die face is essentially perpendicular to the centerline of the extrusion apparatus and meets the wall of the container at essentially a 90° angle. The wall 8 of the extrusion die makes essentially a 90° angle at the die face and is parallel to the centerline of the extrusion apparatus.

The previously described die geometry is typical of the hot aluminum extrusion process. FIG. 3 shows a schematic of the metal flow pattern in the hot aluminum extrusion process. The lines shown on the billet 5 show the deformation process during some intermediate part of the extrusion process. These lines were placed on the billet in a uniform, square pattern prior to extrusion. It should be noted that the first metal to be extruded comes from the center of the billet 10 while the exterior surfaces 11 of the billet are the last to be extruded. In FIG. 3, a die D, having a flat face F, is shown. This process is desirable since any surface oxides and other surface impurities are effectively segregated to the last part of the extruded product. The surface 12 of the majority of the extruded product 13 is clean bright metal having no relationship to the original billet surface condition.

By way of contrast, FIG. 4 shows the conventional hot extrusion process used for most non-aluminum extrusion processes. It can be seen that in this type of process the surface of the billet **11** is extruded at roughly the same rate as is the center of the billet **10** and that therefore the surface condition of the billet is reflected in the surface condition of the extruded product **13.** The die D shown in FIG. 4 has a tapered face T, rather than the flat face shown in FIG. 3.

The difference in these two types of metal flow is basically the result of the container and die geometry, but is also influenced by the presence of lubrication. Lubrication between the billet and the container wall will tend to cause an extrusion metal flow as shown in FIG. 4 whereas the absence of lubrication leads to the flow pattern as shown in FIG. 3. The flow pattern as shown in FIG. 3 is desirable in the extrusion of aluminum for the reasons previously described and it has heretofore been thought to be impractical to apply any form of lubrication during the extrusion of aluminum because of the undesirable and unavoidable change in metal flow pattern from that shown in FIG. 3.

Considerable force is required to extrude metals. It would be highly desirable to reduce the required force both from the standpoint of economy through the reduction of energy consumption and from the standpoint that by the reduction of the required force, extruded products of greater cross-sectional sizes may be formed on existing extrusion presses.

The flow of metal through the die generates a significant amount of heat as a result of the frictional forces between the extruded metal and the die wall. This heat buildup is undesirable from several standpoints. First of all, accelerated die wear results when the temperature of the die rises excessively. Secondly, the die, which is commonly made from heat treated steel, will soften and lose the desirable properties obtained by the heat treatment step. Thirdly, the excessive heat can cause exaggerated grain growth on the surface of the extruded product leading to an undesirable duplex structure which causes problems in the further surface treatment of the extruded product.

Another problem which is encountered in the extrusion process is that the extruded metal tends to buildup on the die wall. This buildup causes a change in the dimensions in the extruded product and also causes objectional surface defects in the extruded product.

The apparatus of the present invention provides a means for providing a lubricant to the walls or lands of the die aperture. Through the use of the present invention a significant reduction in the amount of force necessary to produce a given extrusion can be realized. Briefly, the apparatus of the present invention comprises a metal plate having a hole therein which corresponds closely to the size and shape of the die aperture. This metal plate is placed on the surface of the die and located so that the die aperture and the hole in the plate are in registry. At least one of the mating surfaces between the metal plate and the die has a knurled pattern which serves to prevent intimate contact between the metal plate and the die face. A supply of pressurized lubricant is forced into the knurled space and is directed and guided so that it emerges and coats the die cavity walls therby reducing the friction between the metal being extruded and the die wall. This reduction in friction leads to a reduction in the amount of heat buildup at the die, and a reduction in the amount of metal which builds up on the die wall, and a reduction in die wear.

Referring now to FIG. 5 there is shown one embodiment of the present invention. A metal plate **16** is fastened to the die **2** by fastening means **17.** The plate **16** is located between the flat face **9** of the die and the billet to be extruded. At least one of the mating surfaces between the metal plate **16** and the die face **9** has a knurled pattern **18** which prevents close contact between the metal plate **16** and the die face **9.** The details of the knurled surface will be described at length below.

A hollow lube passage **19** which passes through the die **2** is provided so as to supply lubricant to the space between the plate **16** and the die face **9.** In order to direct the flow of lubricant to the die wall surface **8,** a gasket **20** is used to seal the opening between the knurled passageway **18** and the container wall **1.** In the embodiment shown in FIG. 5 the plate **16** covers the whole die face **9.**

In a practical extrusion process, the container is removed in order to remove the unextruded portion of the last billet before extruding a new billet. Because of the necessity to provide a removable die, it is preferable that the metal plate **16** be inset into the die face **9** as shown in FIG. 6. In FIG. 6, the die face **9** is cut away immediately adjacent to the die wall **8.** The metal plate **16** is dimensioned so as to set into this inset portion of the die face **9.** The gasket **20** is then used as a sealing means between the metal plate **16** and the die itself. In this embodiment the die can be removed without disturbing the gasket **20.** Also shown in FIG. 6 are the lube passage **19,** the knurled surface **18** and the fastening means **17.**

FIG. 7 shows a variety of possible configurations for the edge of the metal plate which is immediately adjacent to the die wall.

FIG. 7A shows that the edge of the metal plate **16** may have a square configuration. In this embodiment then the metal plate **16** would serve mainly as an extension of the die **2** itself.

FIG. 7B shows a metal plate having a rounded edge **21.** The rounded edge would reduce the shearing of the aluminum as it enters the die **2** and would reduce the frictional forces which the aluminum encounters before it enters the lubricated portion of the die.

FIG. 7C shows a metal plate having a beveled edge **22** which would serve much the same function as the rounded edge shown in FIG. 7B.

Also shown in FIGS. 7A, 7B and 7C are the lube passage **19** and the sealing means **20.**

Knurling consists of a pattern of fine grooves on the surface of a solid object. The grooves are usually straight and parallel and one or more patterns may be superimposed one upon the other so as to produce the desired pattern. Knurling is conventionally produced by an embossing process, however, the term knurling as used in this application is intended to cover the grooved patterns produced by any method. The dimensions of the knurling patterns suitable for use in the present invention are as follows: the depth of the individual grooves will generally range from **0.0005** to **0.020** inches and the number of grooves per inch will range from **10** to **50.** The function of the knurling is to uniformly distribute the lubricant about the circumference of the extrusion. In order to achieve this goal, it is necessary that the lubricant pass through a minimum amount of knurling before it contacts the extrusion. The minimum amount of knurling required to achieve a satisfactory lubricant distribution may be specified as follows: the pressure drop encountered by the fluid lubricant as it flows through the knurling must be more than five times the pressure drop encountered by the fluid lubricant as it flows from the reservoir to the knurling. A more uniform lubricant distribution may be achieved by providing an enlarged groove which surrounds the knurled portion and into which the lubricant is introduced. This embodiment is shown in FIG. 8 where groove **15** surrounds knurled portion **13.** More uniform lubricant distribution will also be attained where there are cross passages interconnecting the knurling grooves. This is a preferred embodiment.

It is preferred that the metal from which the plate is made be of approximately the same composition as that from which the die is made so that it will have similar mechanical properties and similar thermal properties such as thermal expansion. In general, the thickness of the plate will be from **0.2** to **1** inch. It is preferred that the plate be made of steel and that it be heat treated after knurling.

A wide variety of appropriate lubricants exist. In general, these lubricants may be characterized in the following fashion:

1. They must be thermally stable at the extrusion temperature, usually about **950°**F maximum, at the pressure at which the lubricant is to be supplied.
2. They must be liquids in the temperature range of **850°** to **950°**F.
3. They must have adequate lubricity and film strength under the conditions that prevail in the die, or they must react with the aluminum surface to form a reactive product which can function as a solid lubricant.
4. No reaction should occur between the lubricant and the die material.

Examples of inorganic compounds that satisfy the above criteria include anhydrous B_2O_3 and mixtures of alkali metal and alkaline earth chlorides that have a liquidus no higher than **450°**F. Systems in the latter area which look particularly promising include KCl-LiCl, NaCl-$MgCl_2$, LiCl-NaCl-$MgCl_2$, LiCl-KCl-$MgCl_2$ and NaCl-KCl-$MgCl_2$. In addition, $CaCl_2$, $SnCl_2$, $ZnCl_2$ and $PbCl_2$ may be added to the above mixture or substituted selectively in all or part for one of the constituents in these mixtures. Stable alkali metal and alkaline earth nitrates may also be employed. Selected organic and metal organic compounds also can meet the above criteria. Organic compounds belonging to the generic polynuclear aromatic family are promising because of their good thermal stability. Examples include $C_{22}H_{14}$, $C_{10}H_7NHC_{10}H_7$, $C_{10}H_7C_{10}H_7$, and also compounds of this general family having ester or amide linkages, such as tricresyl phosphate.

Most of the foregoing lubricants are solids at room temperature. Accordingly, these solid lubricants must be melted prior to applying them to the extrusion process. This heating will preferably occur in a reservoir and the lubricant will be supplied to the die through an insulated connecting passage. Because of the difficulty of pumping molten materials, in a preferred embodiment, compressed air or other gas may be applied to the top of the reservoir to force the liquid into the die. It will probably be necessary to preheat the die so as to prevent the lubricant from solidifying in the knurled space.

The required lubricant pressure will vary greatly depending upon operating conditions and the composition of the lubricant selected. However, the required pressure will in general exceed **500** psi. The lubricant pressure permitted for proper functioning of the present invention may be determined using the criterion that the lubricant pressure will exceed the flow stress of the metal under the conditions encountered by the metal in the die opening. That is to say, the lubricant pressure desired would be that which causes the pressurized lubricant to deform the aluminum being extruded. The compressive flow stress will vary with alloy composition, grain size, temperature and the hydrostatic pressure to which the alloy is exposed within the die. In general, the pressures required will range from **500** to **5,000** psi, measured at the die opening, and preferably from **600** to **3,000** psi.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. In a press for the hot extrusion of aluminum and aluminum alloys having a cylindrical container, an extrusion die with a flat face at one end of said container, and a movable piston within said container at its other end, the improvement which comprises: a metal plate positioned within said container adjacent to said die and conforming thereto, means for attaching said plate to said die, said plate having a flat face adjacent to said die face, at least one of the adjacent plate and die faces having a knurled surface means to furnish a passageway in the region therebetween, and conduit means in said die for supplying lubricant to said region between the metal plate and the die face, whereby to provide lubricant for aiding the extrusion of a billet through said die.

2. A press according to claim **1,** wherein the said knurled surface has **10** to **50** grooves per inch, said grooves having a depth of **0.0005** to **0.02** inch.

3. A press according to claim **1,** further comprising a sealing means between said die and plate sealing said passageway from said container interior.

4. A press according to claim **1,** wherein said die and plate are of the same metal.

5. A press according to claim **1,** wherein the said metal plate is recessed in the said die.

6. A press according to claim **1,** wherein the said conduit means has an entry portion of enlarged cross-section prior to joining said passageway.

* * * * *