United States Patent

Loewenstein et al.

[15] **3,673,667**

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[54] METHOD FOR PRODUCING COMPLEX SHAPES BY FILLED BILLET EXTRUSION

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[73] Assignee: **Whittaker Corporation**

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[52] **U.S. Cl.** **29/423,** 29/187.5, 29/420.5

[51] **Int. Cl.** **B23p 17/00**

[58] **Field of Search** ..... 29/423, 187, 187.5, 192 R, 29/420.5, 481

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[57] **ABSTRACT**

The method of this disclosure comprises the production of solid complex shapes of substantially uniform cross-sectional shape throughout their length from filled billets by extrusion of the latter with either the replica or filler, which together comprise the billets, being formed from a plurality of stacked, thin plates. The plates are preferably indexed and keyed together to maintain the desired complex shape throughout the extrusion step.

8 Claims, 6 Drawing Figures

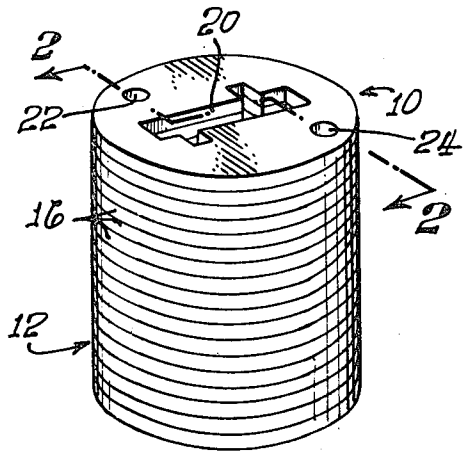


FIG. 1.

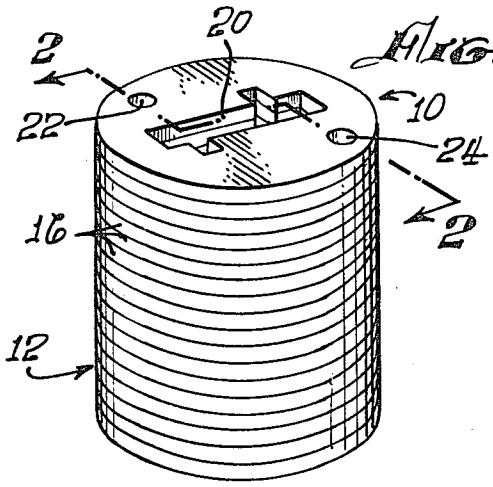


FIG. 2.

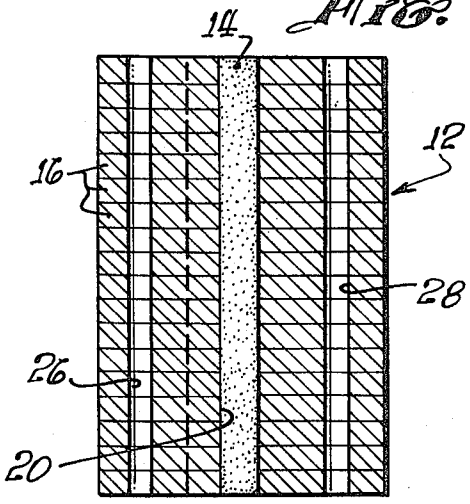


FIG. 3.

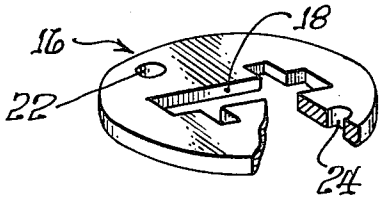


FIG. 4.

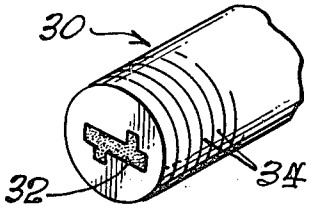


FIG. 5.

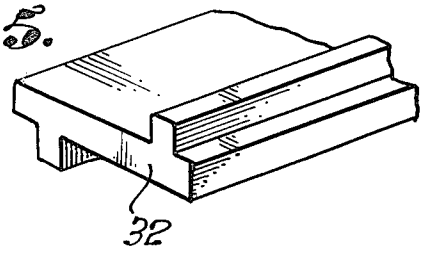
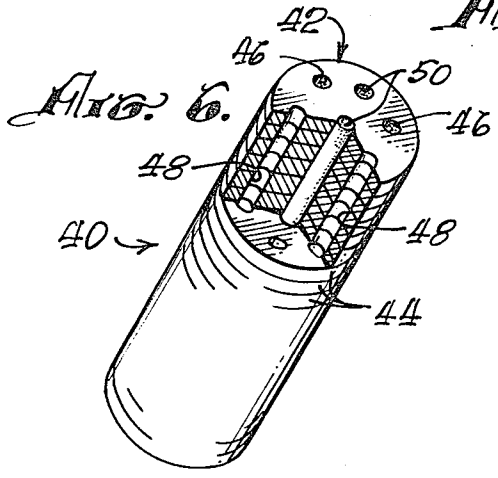


FIG. 6.



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METHOD FOR PRODUCING COMPLEX SHAPES BY FILLED BILLET EXTRUSION

BACKGROUND OF THE INVENTION

This invention relates to metal working and, more particularly, to a method of producing complex metallic shapes of substantially uniform cross-section throughout their length by means of a modified filled-billet technique.

The term "complex shapes," as used herein, refers to shapes such as capital H's, capital T's, capital Z's and other configurations which do not have a solid cross-section. A variety of techniques have previously been utilized to produce complex shapes. However, each of them has had significant disadvantages which have made the production of such shapes a costly process. For example, a presently employed method of producing complex shapes comprises machining the desired shape from solid stock. Such machining is time-consuming and is therefore costly in terms of labor, especially when hard materials such as titanium are used.

Complex shapes have also been formed by rolling billets between specially shaped rollers. However, this method is primarily limited to the more ductile materials, such as the milder steels.

Complex shapes have also been formed by extrusion through shaped dies. However, this method is not always practical when very hard materials such as titanium or superalloys are being shaped, since sharp corners or thin sections in the dies, which may be required to produce the desired shape, often break or bend during the extrusion step. To avoid this problem, a modified extrusion technique known as the filled-billet technique has been developed for such hard-to-extrude materials or very complex geometry. In this technique, an enlarged replica of the ultimate complex shape to be produced is machined from solid stock and placed within an extrusion canister together with filler pieces which are mated both to the canister and to the replica and which hold the replica tightly within the canister. The latter is then extruded through a round die to plastically deform the replica and the filler pieces and, simultaneously, reduce the cross section of the replica and increase its length. Even though the filled billet method constitutes an improvement over other methods for forming complex shapes from refractory materials, it suffers the disadvantage that both the replica and the filler must be machined to a precise fit prior to their utilization. This is generally expensive in terms both of labor and of materials.

A new technique employs powder for the filler and/or replica material. This method is described in a copending patent application entitled "Formation of Complex Shapes by Powder Filled Billet Technique," Ser. No. 882,092, filed Dec. 4, 1969 and assigned to the instant assignee (hereafter referred to as "said copending application"). While the method described in the foregoing application constitutes substantial improvement over prior art techniques for producing complex shapes, it may still be necessary to employ a machined replica or filler in this method. As previously stated, the use of a machined replica or filler is, in itself, relatively costly. Thus, it would be advantageous, even in this improved technique, to be able to employ a solid replica or filler without resorting to the usual costly machining procedures.

SUMMARY OF THE INVENTION

The complex shape forming method of this invention comprises the forming of a replica of a complex shape, but of enlarged cross section and reduced length relative thereto, and a filler having a complimentary shape such that, when mated, the replica and filler together form a rod or billet suitable for extrusion. Either or both the replica and filler is formed by stacking a plurality of relatively thin plates together to form the desired initial billet length with each plate representing, in cross section, an enlarged version of the desired complex shape. Preferably, the plates comprising the replica and/or filler are indexed and keyed to maintain their position and, thus, the overall complex shape, during extrusion of the billet.

If the replica is formed from a plurality of stacked plates, the material constituting the plates will be one which will permit bonding of the plates together during the extrusion step. After the billet is extruded, the filler material is separated from the complex shape product by well-known chemical or mechanical means.

The primary advantage of this technique is that the relatively thin plates employed can be accurately and inexpensively produced by conventional machining, by electro-spark discharge machining, by powder metallurgy and particularly, by stamping. Assembly of the plates to form the filler or replica is also relatively inexpensive. Additionally, the use of relatively thin plates permits the use of even hard materials which are otherwise difficult to machine, but which may readily be stamped.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a billet of this invention from which a complex shape may be formed by extrusion.

FIG. 2 is an elevational cross-sectional view of the billet of FIG. 1 taken along the line 2—2 of FIG. 1.

FIG. 3 is a perspective and partially sectioned view of a single plate employed to form the billet of FIG. 1.

FIG. 4 is a partial perspective view of the billet of FIG. 1, after extrusion, showing the proportional reduction of both the filler and replica.

FIG. 5 is a perspective view of the complex shape produced from the replica and billet of FIG. 1.

FIG. 6 is a perspective, partially sectioned view of a billet illustrating the simultaneous formation of a plurality of complex shapes.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The method of this invention briefly comprises the forming of complex shapes by working, e.g., by extruding, a filled billet comprising a replica of the desired complex shape and a filler which is substantially co-extensive with the replica. Either the replica or the filler is formed from a plurality of stacked, thin plates each of which is shaped to provide the desired configuration. Following working of the billet, the filler material is separated from the complex shape by well-known techniques.

This invention will now be more specifically described with reference to the Figures and, more specifically, to the presently preferred embodiment shown in FIGS. 1–3. In FIGS. 1–3, the numeral **10** designates a billet which includes a filler **12** and a replica **14** of the desired complex shape. The filler **12** comprises a plurality of stacked, thin plates **16** which may be identical to each other as shown in FIG. 1 or which may differ from each other in size as required by the complex shape which it is desired to produce. Each plate **16** has a shaped slot **18** formed therein, for example, by stamping. When the plates **16** are stacked, as shown in FIG. 1, the aligned slots **18**, form an elongated cavity **20** which, when filled, results in the formation of the replica **14**.

Each filler plate **16** is relatively thin with its thickness depending upon a number of factors including the type of metal comprising it and the technique employed to form the plate, for example, machining or stamping. Typical plate thicknesses range from about 0.062 inches to about 0.250 inches. This thickness range provides a satisfactory compromise between material costs and forming costs.

Preferably, the individual plates **16** are indexed and keyed to each other to maintain them in alignment to preserve the shape of the replica **14**, particularly during the extrusion operation. Each plate **16** may be indexed by forming apertures **22,24** therein as shown in FIG. 3. When the plates **16** are stacked to form the billet **10** as shown in FIG. 1, the apertures **22,24** in each plate **16** are aligned to form elongated holes **26,28** respectively in the billet **10**. Keying of the plates **16** may be accomplished by extending bolts (not shown) through the holes **26,28** and threading nuts onto the bolts to pull the plates **16** tightly into facing contact. With the plates **16** assembled,

the shaped slots **18** will be in alignment with each other thereby forming the shaped cavity **20**, and thus, when filled, the replica **14** as required to produce the desired complex shapes. Regardless of whether the plates **16** are indexed and keyed to one another, they are maintained in their stacked position by any appropriate means such as by bolting them together as previously described so that the integrity of the billet **10** will be maintained throughout the extrusion operation.

Preferably, the cavity **20** is filled with a metallic powder as described in said copending application (particularly p. **7**, line **10** to p. **8**, line **3**), to form the replica **14**. When employing a powder as the replica material, a cannister (not shown) may be used to surround the billet to maintain the powder in place in the cavity **20** and to prevent oxidation of the powder when heated by permitting evacuation of the billet. More simply, in some cases, a pair of blank end plates (not shown) may be employed to close the ends of the cavity **20**. After the billet **10** has been assembled and, where necessary, surrounded by a cannister, it is then preferably extruded. During the extrusion step, the powder is consolidated. The resulting extruded rod **30** is a proportionately elongated and smaller diameter version of the billet **10** and includes a complex shape **32** and an extruded filler **34**. Thereafter the complex shape **32** is separated from the extruded filler **34** by well-known chemical or mechanical techniques.

The described preferred embodiment of this invention has particular utility in connection with the simultaneous forming of a plurality of rods or wires of desired diameter and cross-sectional shape. In general, a filler may be formed from a plurality of plates with each plate having a plurality of holes formed therein. When the plate holes are aligned in the assembled filler, bores are formed which, when filled, form replicas of the desired rod or wire products. More specifically, and with reference to FIG. **6**, the numeral **40** designates a cylindrical billet comprising a filler **42** formed from a plurality of stacked plates **44**. Each plate **44** has a plurality of holes **46** extending therethrough. The filler **42** is assembled so that the holes **46** in the plates **44** are aligned to form bores **48** extending through the filler. The bores **48** are filled with a desired metallic powder to produce replicas **50** of the wire or rod products. As shown in FIG. **6**, the holes **46** in the plates **44** are circular. However, this shape is not required and the holes **46** may be, for example, oval.

As previously described, the plates **44** are interconnected and preferably keyed to maintain alignment of the plates **44**. The billet **40** may be closed at its ends by solid end plates (not shown) or by a cannister if evacuation of the billet is desired. The billet **40** is then extruded and the resulting wires or rods are separated from the extruded filler.

The embodiment thus far described, is preferred because assembly of the filler **12** from plates **16** is substantially less expensive than the machining of a solid filler and because the assembled filler **16** automatically provides a cavity into which powdered metal can be poured and retained without otherwise providing a special shell or enclosure for the powder as, for example, when also using a powder as the filler as described in said copending patent application. However, other embodiments of this invention may also be employed. Thus, both the filler **12** and the replica **14**, or the replica alone, may be formed using stacked plates as described. If the replica **14** is formed from a plurality of stacked plates, the material forming the plates must be such as to permit bonding of the plates together to form an integrated complex shape product. If the replica **14** is assembled from plates, but the filler is not, the latter may comprise, for example, a powder or a machined filler. Conversely, if the filler is assembled from plates, the replica **14** may be formed from, for example, a solid body in addition to the powder.

In practicing this invention, it is only necessary that either the replica or the filler be formed from a plurality of stacked plates. Therefore, in addition to the aforedescribed embodiments of this invention employing a combination of stacked plates and powder, either the replica or filler may comprise a simple machined solid or premachined parts separated longitudinally.

The use of a filler to surround the replica is only one relationship which the filler and replica may have. Additionally the replica may surround the filler or, for example, when forming tube-type complex shapes, the filler may both surround and be surrounded by the replica.

Although the use of an extrusion process in practicing this invention is preferred due to the generation of substantially uniform radial and axial forces during the extrusion, other working techniques may also be used. For example, rolling and swaging techniques may be employed in place of the described extrusion technique.

We claim:

1. A method of producing a solid product of complex shape, comprising the steps of:

forming a replica of enlarged cross section and reduced length of said product of complex shape;

forming a filler for mating with said replica to form, in combination, a solid rod, at least one of said replica and said filler being formed from a plurality of thin, stacked plates;

working said solid rod to reduce its cross section to produce said product of complex shape; and

separating the worked filler from said product.

2. The method of claim **1** wherein said stacked plates are indexed and keyed relative to each other to maintain said complex shape during said working.

3. The method of claim **1** wherein said filler is formed from a plurality of said stacked plates and wherein said replica is initially formed from a powder, said powder being consolidated in said complex shape.

4. The method of claim **1** wherein said replica is formed from a plurality of thin, stacked plates of a material which permits inter-bonding of said plates during said working.

5. A method of producing a complex shape product, comprising the steps of:

forming a plurality of relatively thin plates, each said plate having a hole of predetermined shape formed therein;

assemblying a desired number of said plates to form a filler of generally cylindrical shape, said holes in said plates being aligned to form a cavity in said filler and coextensive with the length thereof, the cross section of said cavity being an enlargement of the cross section of said complex shape product and the length of said filler being less than that of said complex shape product;

filling said cavity with a metallic powder; said filled cavity and said filler forming a billet;

interconnecting said plates to maintain the integrity of said filler;

working said billet to reduce its cross section substantially uniformly along its length, said metallic powder being consolidated during said working to produce said complex shape product; and

separating said complex shape product from said worked filler.

6. The method of claim **5** wherein said plates are identical to each other.

7. The method of claim **5** including the step of keying said plates relative to each other to maintain a desired cross-sectional shape of said cavity.

8. The method of claim **5** wherein each said plate has a plurality of holes formed therein and extending therethrough, said holes forming a plurality of cavities when said filler is assembled, whereby a plurality of complex shapes are simultaneously produced by working said billet.

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