

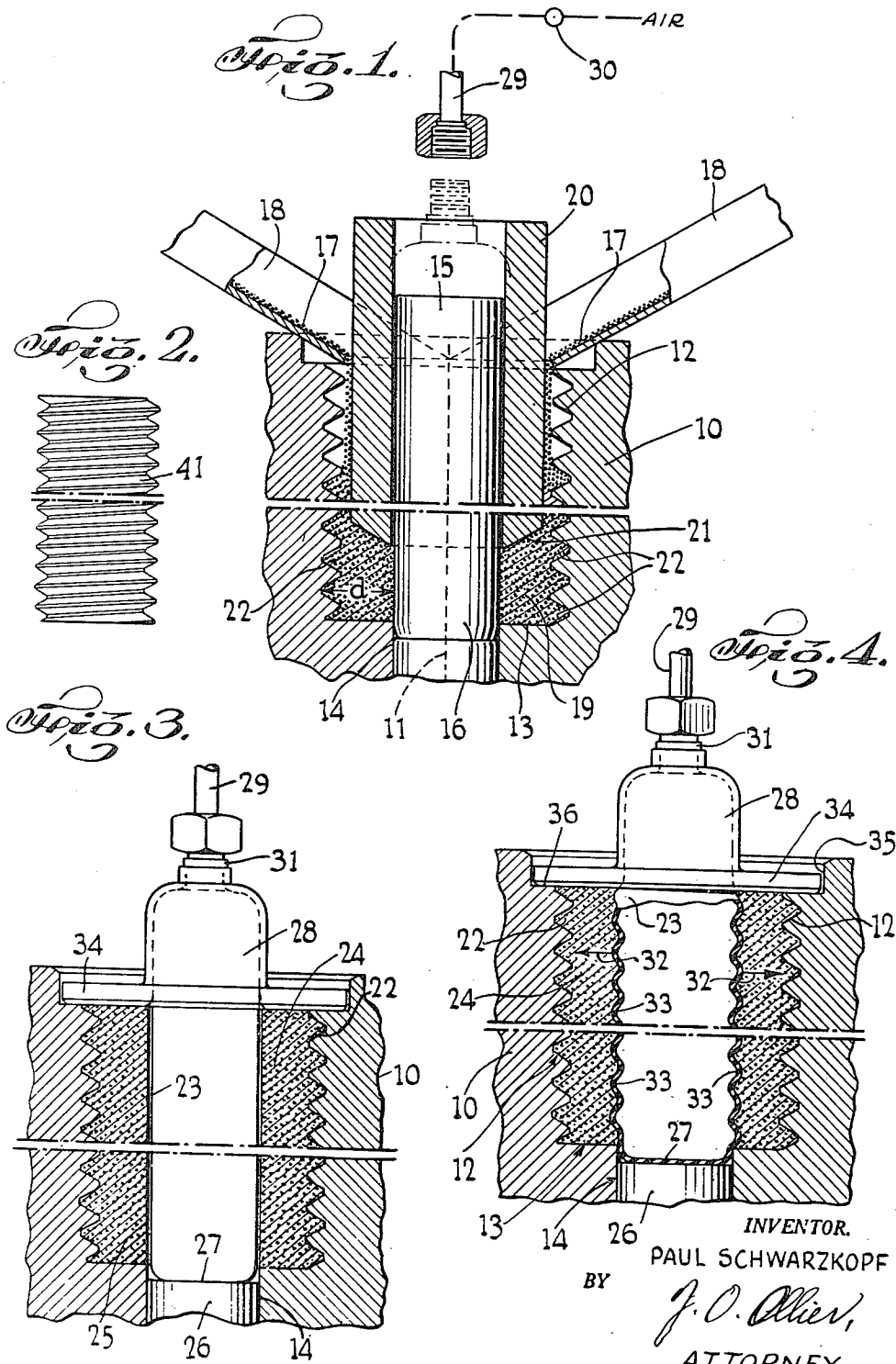
Aug. 17, 1948.

P. SCHWARZKOPF
METHOD OF COMPACTING METAL POWDER
INTO COMPLICATED SHAPES

2,447,434

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3 Sheets-Sheet 1



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Fig. 5.

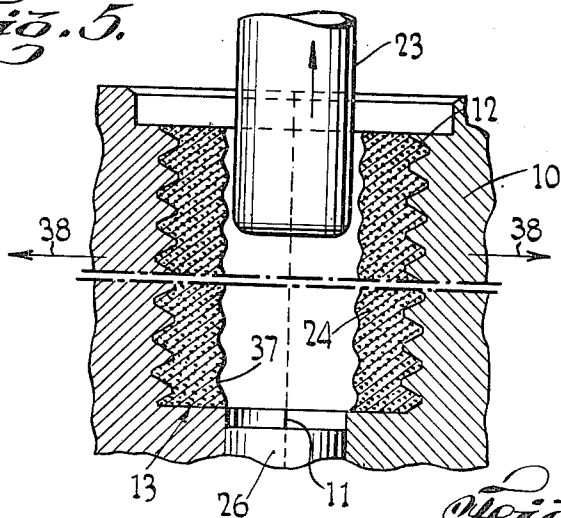


Fig. 6.

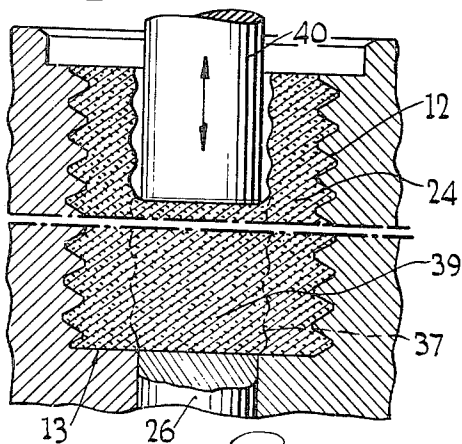


Fig. 7.

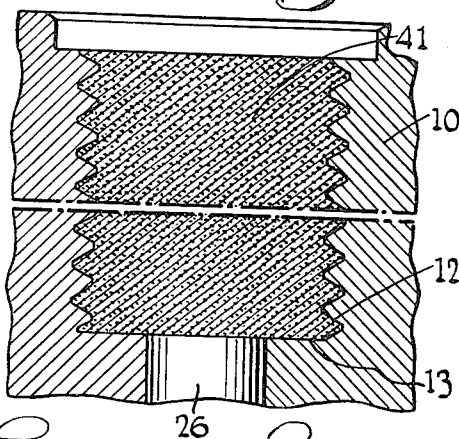


Fig. 8.

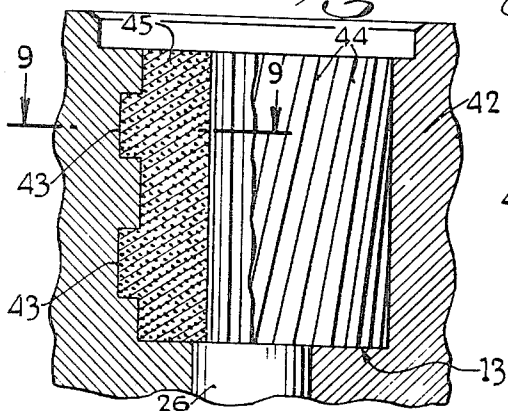


Fig. 9.

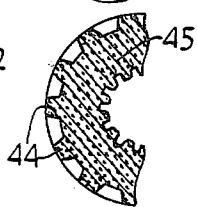
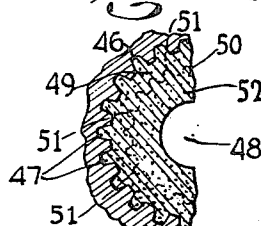


Fig. 10.



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Fig. 11.

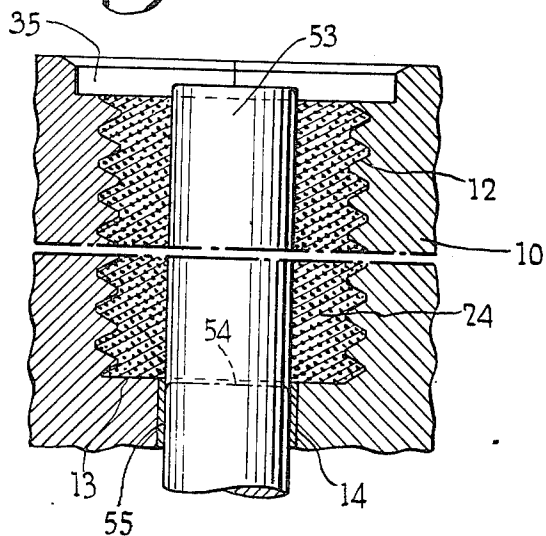


Fig. 12.

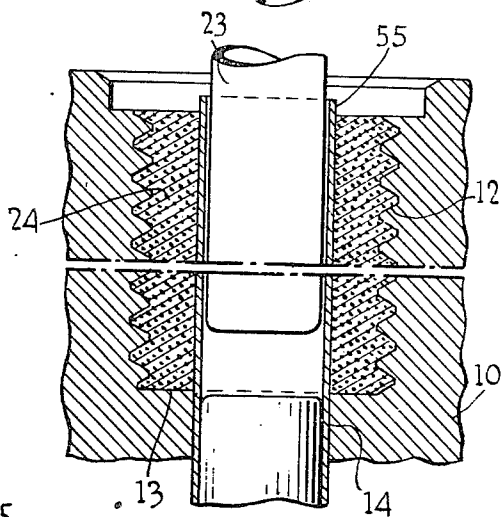
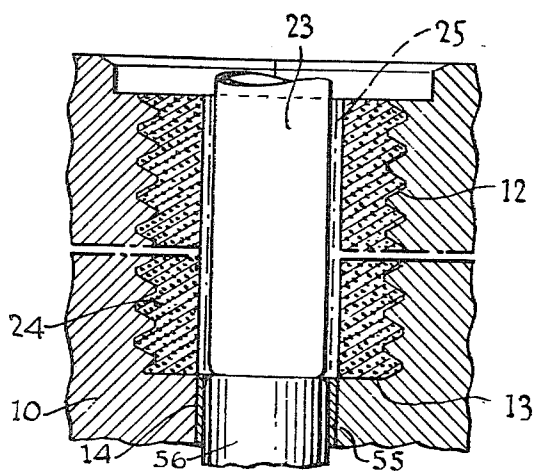


Fig. 13.



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METHOD OF COMPACTING METAL POWDER
INTO COMPLICATED SHAPESPaul Schwarzkopf, Yonkers, N. Y., assignor to
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4 Claims. (Cl. 29—160.5)

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This invention relates to the manufacture from powdery metallic material of compacts and consolidated articles of rather complicated shape and particularly provided with off-sets, undercuts, recesses and/or projections which may necessitate the use of split molds in shaping the powder under pressure.

As is well known in the art of powder metallurgy, metallic powder of suitable particle size and in general between about 100 to less than one micron average diameter of the individual particles, has flow characteristics which render it difficult to compact the powder into shapes of rather complicated configuration, such as provided with steps, undercuts, recesses and/or projections as exemplified by screw threads, threads and teeth. The pressure exerted upon the powder in the mold is translated in the powder essentially in the direction of pressure and to far smaller or no extent at an angle to it. Furthermore, the pressure translated into the powdery body diminishes both axially and laterally with the distance from the pressing surface. Therefore, even in pressing a cylindrical body, the compression of the powder in the mold under the punch is not uniform in that the compression is greatest in the center and least at the sides, resulting in a kind of cone or paraboloid of highest compression or particle concentration under the pressing surface of the punch. This flow characteristic of metallic powders can be improved, but to a limited extent only, by the admixture of lubricants to the powder which are volatile at temperatures below sintering temperature, such as paraffin and compounds including stearic acid.

It is an object of the invention to facilitate or render it possible to press to shape metallic powders with or without admixed lubricants, into rather complicated shapes under which is understood herein and in the appended claims, a shape having off-sets, undercuts, projections and/or recesses, and particularly shapes which necessitate the use of a split mold.

It is another object of the invention to compact more uniformly than heretofore possible, metallic powders into rather complicated shapes, and in particular in split molds.

It is still another object of the invention to compact metallic powders into rather complicated shapes so that the powder in projections, such as threads or teeth extending in any direction, is compacted as uniformly as possible and forms a coherent mass in those projections.

It is a further object of the invention to com-

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press both in axial and lateral direction, metallic powders into rather complicated shapes so as to obtain a compact which can be removed from the mold and handled thereafter without deteriorating such as cracking or crumbling the projections.

It is still a further object of the invention to compact metallic powders particularly, but not exclusively, in a split mold into rather complicated shapes so that the compact is of an as uniform as possible density.

These and other objects of the invention will be more clearly understood as the specification proceeds with reference to the drawings in which Fig. 1 shows by way of exemplification, in vertical cross section and partly in elevation, a split mold for compacting a screw-threaded body from metallic powdery material and a punch used in a first step according to the invention, Fig. 2 in elevation and on a smaller scale, the compacted body finally obtained, Fig. 3 in a similar manner as in Fig. 1, a second step of the invention in its initial stage with a flexible and resilient, expansible body inserted into the powdery mass pressed or charged into the mold, Fig. 4 in similar manner the second step of the invention in its final stage with the expansible body inflated or expanded, Fig. 5 in a similar manner the removal of the deflated, expansible body after completion of the second step of the invention, Fig. 6 in similar manner the progress of a third step of the invention with a punch pressing additional material into the hollow compact or shell, Fig. 7 in a similar manner the solid compact in the mold after completion of the third step of the invention, Fig. 8 in cross section and partly in elevation, a mold and a spiral gear shape compacted therein, Fig. 9 a part-section through the spiral gear taken along line 9—9 in Fig. 8, Fig. 10 a cross section through a part of another body of complicated shape compacted in a mold to form a spur-gear, Fig. 11 a modification of the invention, and Figs. 12 and 13 another modification of the invention at the end of the first and start of the second step, respectively.

Referring to Fig. 1, 10 is a mold or die split along a vertical plane 11 for the production therein from powdery metallic material to which a lubricant of the type mentioned hereinbefore may have been admixed, if desired, a hollow or solid body 41 screw-threaded on the outside as shown in Fig. 2 on a smaller scale. The mold cavity is formed by a screw-threaded side face 12, which is the negative of the screw thread to

be formed on the outside of the compact, and a bottom 13 having a center hole 14. A preferably hollow and thin-walled metallic body 15 of slightly larger diameter than hole or bore 14 and having a downwardly tapering end 16 is fitted with the latter into hole 14. The radial or lateral distance between the outside of body 15 and a point furthest from it in the side face 12 is such that lateral or radial pressure exerted thereafter upon the powder is translated uniformly through it. The desired metallic powder 17, e. g. of bronze, iron, steel, alloy steel or a mixture of steel and pure iron, is then fed in measured quantity, e. g. through one or more chutes 18 into the annular space between the outside of body 15 and surfaces 12, 13. After a predetermined amount of metal powder 19 has been deposited in the mold cavity, a ring-shaped punch 20 the lower pressing surface 21 of which tapers downwardly at a suitable angle, is lowered under pressure into the annular mold cavity so as to compress therein the powdery mass 19. The incline of pressure face 21 is such that the powdery mass 19 is displaced both downwardly as well as laterally and thereby pressed in to the groove 22 to form the thread. After the first amount 19 of powder has thus been compacted to a certain degree or at predetermined compression ratio, punch 20 is withdrawn and another amount of powder 17 fed into the annular mold cavity; thereupon punch 20 is lowered again under pressure, and thus alternating feeding of powder and compressing is continued until the mold cavity is filled entirely with metallic powder which now forms a hollow pre-compacted body or shell 24, Fig. 3.

Hollow punch 20 is then moved laterally from the space above the opening of mold 10, and a flexible tube closed at its lower end or bag 23, for instance of rubber, Fig. 3, is lowered into the hollow body 15 which is thereafter withdrawn upwardly. Alternatively and as it is assumed in Fig. 3, body 15 is removed from the pre-compacted or tamped hollow body 24 before bag 23 is introduced into hole 25; in order to prevent crumbling of surface layers around hole 25, bag 23 is slightly spaced from the latter as shown in Fig. 3. A cylindrical support 26 for bottom 27 of tube or bag 23 is moved from below into bore 14. The upper end of bag 23 is air- or liquid-tightly fitted into a member or bell 28, provided with a hollow nib 31. A flexible duct 29, for instance a rubber or metal hose, Fig. 1, is connected with nib 31 and communicates through valve 30 with a source of compressed fluid, such as an air-compressor, a container for air or liquid under pressure, a water pump and the like. After tube or bag 23 has been lowered in any suitable manner into hole 25 of the tamped or precompacted body 24, fluid under pressure is admitted into bag 23 so as to forcibly expand it. Member or bell 28 is held in position e. g. by mechanical means, such as a ram or lever (not shown), and bag 23 can expand under the pressure only laterally or radially into the tamped or pre-compacted mass 24.

Fig. 4 shows the stage when the final pressure has been reached within bag 23. Bag 23 translates the pressure upon the pre-compacted mass 24 laterally or radially in the direction of arrows 32, and mass 24 will give wherever it faces or is in the recess 12 and is less pre-compacted than outside this recess. As a consequence, bulges 33 result in bag 23 wherever it faces the thread-recess 12 in the mold 10. The pre-compacted

powder mass outside the recess is also compacted radially and additionally.

In order to prevent the powder mass near the top of the mold cavity from being pressed upwardly by expanding tube 23, member 28 is provided with a flange 34 which completely covers and preferably projects beyond the filling opening of the mold cavity into cylindrical recess 35, Fig. 4, and rests on shoulder 36.

After mass 24 is fully compacted to predetermined density and coherence, pressure is released from bag 23 for instance by turning valve 30 which is a three-way valve. The deflated bag can be easily removed in the manner shown in Fig. 5. The cylindrical surface of hole 25 in the pre-compacted body 24, Fig. 3, is now changed to a kind of threaded surface 37, and the innermost or smallest diameter of that surface larger than the diameter of hole 25 and of deflated bag 23.

If the finally compacted shape 24 can be used for the ultimate purpose, the process according to the invention is now completed, and mold or die 10 can be opened by moving its parts or halves in the direction of arrows 38, Fig. 5. A proper die holder for the split die 10 is conventional and not shown. Compact 24 is of sufficient density and coherence so that it can be taken out of the opened mold and handled thereafter, particularly sintered in a proper furnace, for instance of the push furnace type.

If it is desired to produce a solid compact, the hollow compact 24 is left in die 10 after bag 23 has been removed, Fig. 5, and support 26 is lifted so that its upper surface is flush with bottom 13 of the die cavity, as shown in Fig. 6. Thereafter additional powdery material 39 is filled into hole 37 of compact 24 and compressed by punch 40. Preferably several measures of powdery material are successively fed into hole 37 and tamped therein until it is filled entirely, Fig. 7, or to predetermined height, with powder preferably compacted to the same density as compact 24. A solid compact 41, Fig. 7, threaded on the outside is thus obtained. Split mold 10 is then opened and the compact 41 removed, whereupon another cycle of operation can be started.

If a hollow or solid compact suitable for a spiral gear is to be made, a split mold 42, Fig. 8, is used the cavity of which comprises recesses 43 in which the spiral projections 44 are shaped. The method of compacting the hollow or solid body 45 is otherwise the same as hereinbefore described.

The utility of the invention is not limited, however, to compacting bodies from powdery initial material which are provided with lateral projections such as screw-threads of various pitch, or result in undercuts which necessitate the use of a split mold. The invention is equally useful wherever the thickness of the body varies in a direction lateral or radial to that of the pressure which can be exerted upon the powder in the mold cavity by one or more punches. If, for instance, a compact 49 suitable for a spur-gear, Fig. 10, is to be pressed, the teeth 47 of which are essentially parallel to the axis 48 of the body and the direction of pressure exerted by punches lowered into the mold cavity, powder is filled and pre-compacted in cavity 46 so as to form first a kind of shell therein. Then the flexible pressure means, such as a rubber bag, is introduced into the cylindrical hole of the shell and pressure produced therein whereby the bag is inflated as shown in dotted lines 50 in

Fig. 10; its bulges 51 face the projections or teeth 47 and extend co-axially with axis 48 of the body. After shell 49 has been finally compacted, bag 50 is deflated and removed, and e. g. another shell 52 compacted in shell 49 in a similar manner as the solid portion 39 in Fig. 6.

From the above exemplifications of the invention it will be realized that it consists essentially in forming first in the mold cavity a kind of shell or hollow body from the powdery material, which is pre-compacted so as to increase its density. The thickness of the shell or hollow body measured in a direction lateral or perpendicular to the direction of pre-compressing the powder in the mold, is chosen so that in the subsequent step according to the invention in which a lateral or radial pressure is exerted, the latter is translated as uniformly as possible through the powdery shell. Therefore, if the thickness of the hollow body to be compacted exceeds that which permits uniform lateral or radial compression according to the invention, the body is to be sub-divided virtually into two or more co-axial or concentric hollow bodies, the outermost of which is first compacted in the manner hereinbefore described, whereupon a second hollow body is compacted within the first one, and so on until either a hollow body of desired thickness or a solid body is obtained.

Instead of using a solid or hollow body 15, inserted from above into mold 10, Fig. 1, according to the modification shown in Fig. 11, a mandril or core rod 53 is raised through bore 14 into the position shown in full lines. After the powder has been filled into and compacted or tamped in the annular cavity between the surfaces 12, 13 and core rod 53 in the manner described with reference to Fig. 1, to form a pre-compacted shell 24, mandril 53 is lowered to the position shown in dotted lines; preferably while mandril 53 is so lowered, the expansible means 23 is introduced into the hole of shell 24 and rests on the upper surface 54 of the mandril in its lowermost position.

Instead of using solid mandril 53, a tubular mandril 55, Fig. 12, can be used in the raised position of which the powdery material is filled into the mold cavity to form the pre-compacted shell 24. The expansible means or bag 23 is inserted into hollow mandril 55 at any time before the latter is lowered into the position shown in Fig. 13, so that the means 23 is in position within hole 25 when mandril 55 is so lowered. A support 56 fitting inside mandril 55 is moved into the position shown in Fig. 13 so that the expansible means or bag 23 can rest on it (and on the upper surface of mandril 55) during its subsequent expansion or inflation.

If a compact of rather complicated shape with projections and/or recesses parallel to the axis of the mold cavity is produced according to the invention, for instance as described with reference to Fig. 10, either a split mold or a solid mold can be used. In the latter event, support 26, or a core rod, or a hollow mandril with inserted supporting rod, can also be used for ejecting the completed compact from the mold cavity.

The pressure to be exerted upon the powder by punch 20, Fig. 1, depends upon the nature and particularly the flow-characteristics of the powder and may vary for instance between about 1 and 5 tons per square inch, though it may be higher as well known in the art. The lateral pressure exerted by the resilient pressure means 23 can be of similar or smaller order, depending upon the strength of the bag. Since the latter is sup-

ported at its bottom and upon inflation pressed into the powder, it should be clear that the finer the powder, the greater can be the pressure produced inside the bag and translated upon the powder without tearing the bag. Instead of a bag of any suitable resilient material, other radially expansible means can be used, for instance a longitudinally split core member the complementary parts of which are wedge-shaped and can be displaced relative to one another in order to increase the overall diameter of the core member. The core member can also be composed of several sections which can be laterally displaced by a wedge member driven between them.

A compact completed according to the invention can be further densified and consolidated in any known manner, such as by subjecting it to full sintering, or to a pre-sinter followed by repressing and a final sinter, or by final sintering under pressure. The sintered compact can thereafter be subjected to mechanical and/or heat treatment of any known nature and effect, which is applicable to the metal, mixture and/or alloys of metals (which also may comprise a minor addition of non-metallic material) of which the compact consists.

What I claim is:

1. In a method of producing from metallic powder a cored article having peripheral projections, the steps of providing a die cavity having a rigid peripheral surface including recesses forming the negative of molded projections, providing a removable rigid core within said cavity, filling metallic powder into the space between the surfaces of said cavity and core, exerting pressure in a direction essentially coaxial with the core to preform a cored compact, replacing the core by a radially expansible pressure means, and expanding the latter radially to additionally and uniformly compress the preformed powder compact.

2. In a method set forth in claim 1, providing a hollow removable core within the die cavity, inserting the radially expansible pressure means in the hole of said core, removing the hollow core after preforming the cored compact, and expanding thereafter said pressure means.

3. In a method as forth in claim 1, removing the expansible pressure means from the hole of the cored compact, filling into said hole another layer of metallic powder, and compacting said layer within said hole.

4. In a method as set forth in claim 3, compressing the layer of metallic powder in the hole of the cored compact to a density approximating that of said cored compact.

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