

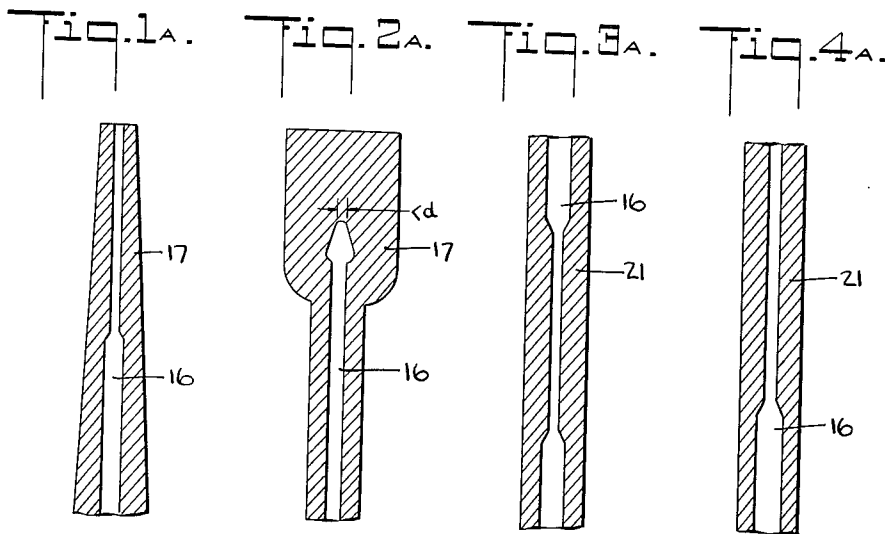
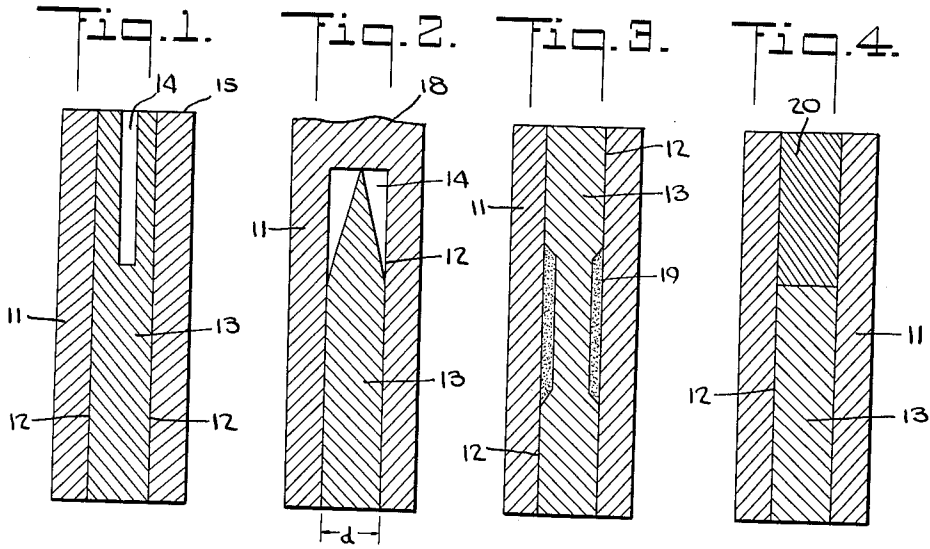
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PROCESS OF PRODUCING HOLES WITH REDUCED OPENINGS

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3,201,856
**PROCESS OF PRODUCING HOLES WITH
 REDUCED OPENINGS**

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The present invention relates to the production of metallic objects having holes therein and, more particularly, to the production of metallic turbine structures having cooling passages therein.

A known kind of process for the production of a blank for a turbine or compressor blade with cooling passages extending longitudinally through it comprises making holes in a billet, filling them with rods of a material having properties of flow similar to those of the billet, deforming the billet to a blank with consequent elongation of the filled holes and finally removing the filler to leave the holes as the cooling passages. In practice, the holes are made in the billet by drilling and so are of uniform cross section throughout their length. Normally, such uniformity of cross section is desirable. In some blades, however, the tip section is exceptionally thin and in order to obtain a passage of substantial cross section in the main body of the blade, it is necessary to reduce the area of the cross section of the passage in the tip region. In other blades it is necessary for the passages to be of smaller cross-sectional area close to the root, and even over a substantial length from the root, than at the tip. Broadly, it may be necessary to make the cross-sectional area of a passage vary over its length. Although attempts were made to provide a simple process for producing blades and other turbine structures having cooling passages of non-uniform cross-sectional area, none, as far as we are aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that by means of a particularly controlled sequence of operations, a remarkably simple process for the production of metallic objects having internal passages of complex cross-sectional sizes can be provided.

It is an object of the present invention to provide a novel process for the production of metallic objects having internal passages of non-uniform cross-sectional area.

Another object of the invention is to provide a novel process for the production of turbine structures having internal passages of non-uniform cross-sectional area.

The invention also contemplates providing a novel process for the production of fluid-cooled turbine blades having internal passages of non-uniform cross-sectional area.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawing in which:

FIGURES 1, 2, 3 and 4 are cross-sectional views of filled metallic masses or billets employed in the process of the present invention; and FIGS. 1A, 2A, 3A and 4A are cross-sectional views of worked structures produced from the masses of FIGS. 1, 2, 3 and 4, respectively, by the use of the process of the present invention.

According to this invention, the resistance to deformation of the billet presented by the filler rods is reduced over a length from one end of a billet with the result that under substantially uniform deformation forces the cross-sectional area of the deformed filled holes becomes less over that length than over the remaining length of the holes. If the passages should be smaller at the tip, the resistance to deformation usually need be reduced over a short length of filler rod only.

Usually, if it is necessary to vary the cross-sectional area of any of the final holes over their length at all, it is necessary so to reduce the area of all of them. Naturally, however, if the shape of the blade is such that some of the holes can be of uniform across section throughout their length, the invention is employed only in the production of the remaining holes.

The deformation is most conveniently effected by extrusion. If the billet is only partially extruded so as to leave in the extrusion container a length of billet which is to form the root of the blade and the passages should be smaller at the tip, the resistance to deformation of the billet is, of course, reduced at the end that leads during the extrusion. If the billet is extruded as completely as possible so as to provide an extruded product that after removal of a short length of the trailing end is of uniform cross section throughout its length, the resistance to deformation may be reduced from either end of the billet.

The preferred way of reducing the resistance to deformation is to fill one length of each hole only incompletely. Thus, over this length each filler rod may be drilled to provide an internal cavity concentric with the outer wall of the rod; or a slot may be cut in each rod from the end; or a length of the rod may be made frusto conical instead of cylindrical. In each case, the metal of the billet will fill the resultant cavity and the final passage will be reduced in cross section in accordance with the reduction in the cross-sectional area of the filler rod. The extent to which this area can be reduced is limited by the risk of cracking and depends in part upon the composition of the billet. With a billet of nickel-chromium-cobalt alloy (18% to 21% chromium, 15% to 21% cobalt) containing aluminum and titanium and of the kind commonly used in gas turbines, the maximum permissible reduction in area is not more than about 60%. With a nickel-chromium-cobalt-molybdenum alloy billet for use at higher service temperature (13.5% to 16% chromium, 18% to 22% cobalt, 4.5% to 5.5% molybdenum) and containing aluminum and titanium, the maximum permissible reduction in area is not more than about 35%. If desired, the cavity in the filled hole may be filled with a particulate material, e.g., alumina, the proportion of voids in this material then determining the shape of the final passage. Such a particulate material may be kept in place by a weld deposit over the end of the hole. The use of a particulate material may be beneficial when the incompletely filled hole is in the root metal and the exclusion of air is desirable to keep irregularities to a minimum.

Another way of reducing the resistance to deformation is to use a length of filler rod of weaker material than that of the remaining length. For instance, the latter length may be an iron-manganese-titanium alloy as described in U.S. Patent No. 2,941,281 and the former length may be mild steel.

The process of the present invention is particularly described in reference to the drawing. Referring now thereto, FIGURES 1 to 4 show billets 11 of heat resistant metal having at least one hole 12 of uniform cross-sectional area extending therethrough which hole 12 is at least partly filled with filler body 13. Filler body 13 is positioned in hole 12 so that an ascertained zone of enhanced flowability is present in hole 12. For example, in FIG. 1, the ascertained zone of enhanced flowability is provided by void 14 in filler body 13 extending from leading end 15. After working by extrusion and removal of filler body 13, passage 16 of non-uniform cross-sectional area in turbine blade 17 is produced as shown in FIG. 1A. Likewise, in FIG. 2, void 14 provided by employing partly tapered filler body 13 is the zone of enhanced flowability. When billet 11 is extruded with end 18 trailing, the passageway in the root (*d* FIG. 2) closes

to (<d FIG. 2A) and is smaller than the original hole, this closure is brought about by the flow of metal near the radius of the extrusion die. This is useful where the finished root shape 17 is very slim. The zone of enhanced flowability can be a non-compacted mass of ceramic particles 19 as shown in FIG. 3 or it can be a relatively weak metal body, e.g., mild steel, such as shown at 20 in FIG. 4. The configuration of passage 16 in worked metal 21 resulting from the extrusion of billets 11 of FIGS. 3 and 4 and removal of the filler body therefrom are shown in FIGS. 3A and 4A, respectively.

The present invention is particularly applicable to the production of hollow fluid-cooled turbine blades, cooled nozzle guide vanes, and foraminous components for rocket motors made from heat resistant metal.

With respect to the manufacture of turbine blades by means of the novel process, it should be understood that the term "heat resistant metal" is used to include austenitic nickel-chromium alloys, including nickel-chromium-iron and nickel-chromium-cobalt and cobalt-chromium alloys, including cobalt-chromium-iron alloys, which contain a total of at least about 25% nickel plus chromium, cobalt plus chromium or nickel plus chromium plus cobalt (i.e., a total of at least about 25% of chromium plus nickel and/or cobalt) in addition to small amounts of aluminum, titanium, molybdenum, tungsten, niobium, tantalum, silicon, manganese, zirconium and boron which may optionally be present in the alloys. The balance of the alloys, if any, is iron. These alloys are adapted to be subjected in use to temperatures up to about 700° C. or above and, accordingly, must be hot worked at temperatures around 1200° C. Fillers such as the aforementioned iron-manganese-titanium alloy and mild steel can be conveniently removed from the heat resistant metal by selective dissolution in an aqueous solution of a common mineral acid.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

We claim:

1. A process for producing a worked metallic object having at least one passage of controlled non-uniformity of cross-sectional area which comprises providing a metallic mass having at least one hole of substantially uniform cross section therein, at least partly filling said hole with a filler body extending throughout the length of said hole and having reduced resistance to deformation over only a portion of the length thereof, to provide at least one predetermined zone of enhanced flowability and at least one predetermined zone of flowability less than the flowability of the zone of enhanced flowability, working the metallic mass together with said filler body under sub-

stantially uniform deformation forces to induce flow of said metallic mass and said filler body and thereafter removing said filler body from the thus-worked metallic mass to open the thus-produced passage of controlled non-uniform cross-sectional area.

2. A process as set forth in claim 1 wherein at least one hole of substantially uniform cross section in the metallic mass is filled only incompletely with a filler body extending throughout the length of the hole.

3. A process as set forth in claim 2 wherein particulate material is provided in an incompletely filled portion of the hole.

4. A process as set forth in claim 1 wherein at least one hole of substantially uniform cross section in the metallic mass is completely filled throughout the length with filler rod and in which a length of the filler rod is of weaker material than that of the remaining length of filler rod and fills the zone of enhanced flowability.

5. A process for producing a worked heat resistant metal object having a plurality of passages of controlled non-uniformity of cross-sectional area which comprises providing a billet of heat resistant metal having a plurality of holes of substantially uniform cross section therein, at least partly filling said holes with a filler body extending throughout the length of said holes and having reduced resistance to deformation over only a portion of the length of said holes to provide at least one ascertained zone of enhanced flowability in each of said holes and also at least one predetermined zone of flowability less than the flowability of the zone of enhanced flowability in each of said holes, working the billet together with said filler body by extrusion to induce flow of said heat resistant metal and said filler body and thereafter removing said filler body from the thus-worked heat resistant metal to open the thus-produced passages of controlled non-uniform cross-sectional area.

6. A process as defined in claim 5 wherein the heat resistant metal object is a turbine blade and the zone of enhanced flowability is adjacent the leading edge of the billet during extrusion.

7. A process as defined in claim 5 wherein the heat resistant metal object is a turbine blade and the zone of enhanced flowability is in the root metal of the billet during extrusion.

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