

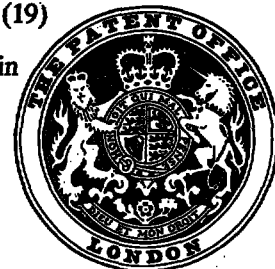
PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO A METHOD OF PRODUCING A FORMING TOOL

(71) I, LARS MAGNUS SEVERINSON, of Östra Hyllievägen 99, 216 22 Malmö, Sweden, a subject of the King of Sweden, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a method of producing a forming tool of the kind having a forming surface on a support body and to such a tool for example a die which could be used for pressing sheet metal or a mould for pressure forming a plastics material.

British Patents Nos. 1 541 446 teaches a method of producing a forming tool which has a forming surface provided on a metal shell and shaped from a pattern and bonded with a support backing which is produced by casting or by sintering of a metal powder matrix on the rear face of said metal shell and at least part of said metal shell being formed by a layer of metal supplied by a metal vapourization process.

One of the objects of the present invention is to improve forming tool production technique and especially the production of forming tools which comprise support bodies of sintered materials which have forming surfaces arranged thereon.

According to the present invention a method of producing a forming tool as herein defined and having a forming surface includes using a pattern of a material capable of resisting a predetermined temperature and having a pattern surface which forms a negative picture of said forming surface, forming a body of mouldable sinterable material in contact with said pattern surface, said mouldable material being sinterable at a sintering temperature which is lower than said predetermined temperature and which before being sintered can be brought into a relatively easily shapable condition and which, when sintered, will

form a relatively porous sintered support body, sintering said body when still in contact with said pattern surface before, during or after infiltrating and filling the pores of said body, at least over a portion thereof adjacent said pattern surface, with an infiltrating material which is either solid and is caused to become liquid and flow by an increased temperature below the said sintering temperature and which solidifies when cooled, or a material which is liquid on being infiltrated and is caused to solidify by baking at a temperature below the sintering temperature, and causing said infiltrating material when liquid, to penetrate into the pores of said forming surface in contact with said pattern surface and also to reach said pattern surface and to be formed thereby when solidified.

In the forming tool according to the invention the entire forming surface is thus formed by material that has been shaped from a surface which is not molten into the mould or tool during the sintering operation or the simultaneous or subsequent infiltration, but instead the infiltration material is brought to melt and penetrate up to, and be formed by, the shaping surface.

The support material may be a metal powder mass of the kind used for conventional industrial production of sintered details of metal. Preferably, however, the sintering of the body is interrupted when the material of which the body is formed is bonded by the sintering effect into a continuous skeleton of grains before infiltration of the pores of the body is effected. The sintering temperature must not be so high that the pattern is deformed and should for the sintering of iron-based metal powder not exceed about 1200°C.

Hardening can be effected if the thus sintered, porous support body consist of hardenable material, such as carbon steel, chromium steel etc.

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According to the invention, the sintered, porous support body can be sealed by infiltration of another metal having a lower melting point than the material of the support body and a lower melting point than the sintering temperature used. Of course, a metal or metal composition compatible with and "wetting" the supporting body should be chosen. If sintering of the support body material has resulted in shrinking, this tendency can be compensated or inhibited by using a suitable infiltrating material which tends to balance the shrinking tendency by filling the heat expanded pores and preventing contraction during cooling.

Thus the method can include sintering the body shaped from a metal powder mixture at a temperature and for a time which are selected so that an initial bond of the metal powder grains is attained, lowering the temperature and calculating the volume reduction after sintering, selecting a suitable volume compensating or stabilizing infiltration material on the basis of said calculation, and then increasing the temperature to a level suitable for volume compensation or stabilizing infiltration of the body, and carrying out the infiltration with the selected material.

The infiltration can be performed by placing metal on the sintered support body and melting said metal into it. Melting can be effected in a furnace or can be realized by any other source of heat, and infiltration can also be performed in such a way that only said forming surface and an adjacent layer of the support body are infiltrated.

The direction of infiltration can be in a direction from the interior of the body to said forming surface.

The use of a fine-grained metal powder mass results in a relatively dense structure having fine pores and which after infiltration has a satisfactory strength and a smooth forming surface. Sintering can be effected to a desired sintering stage, and the sintered body can be hardened. By using a fine-grained metal powder and by performing the sintering for a relatively short time and at a relatively low temperature the shrinking tendency can be reduced and a strong skeleton with fine pores can be obtained which may be filled with another metal for sealing of the sintered body as set forth above.

It has proved to be of particular advantage to use fine-grained metal powder which before use is subjected to a grain-deforming cold working operation whereby the grains are brought into state of stress which is released at the sintering process. It has been found that such a powder can be made sufficiently compact by vibrations only, e.g. so-called ultra sound vibration, and that the sintering temperature can be lowered.

Heat treatment and hardening to a high strength can be effected without deterioration of the surface structure of the forming surface, and dimensional stability or compensation can be attained by suitable choice of sealing or infiltration material which is molten into the sintered body. The infiltrating material which penetrates the forming surface of the body and comes into contact with the pattern can be prevented from bonding therewith by treating the pattern surface with a suitable releasing agent for example a salt readily soluble in a liquid, such as common salt (NaCl) which is dissolved when release is desired by dipping the pattern and the sintered body into water. The sintered body can then usually be readily separated from the pattern body which may consist of any suitable material which is mainly selected with regard to machinability or mouldability, surface finish, heat resistance, heat expansion and dimensional stability at prevailing temperatures.

Instead of infiltrating another metal by melting into the sintered body the metal may be infiltrated for instance from solutions or electrolytes. So-called currentless metal deposition is also possible.

The support body can also be produced from ceramic material. The forming surface can again be formed directly on the shapable sinterable mass by applying said mass directly onto the pattern (which is first treated with a mould release agent).

The structure of the forming surface can be improved by the infiltration technique described. A suitable infiltrant metal can thus be molten into the sintered body so that metal reaches the surface of the pattern. The forming surface of the support body can thus be sealed by the infiltrant metal which may be caused to form the greater portion of the area of the forming surface.

Copper and beryllium copper have proved to yield very satisfactory results as infiltration material in sintered support bodies of metal powder. There are many beryllium bronzes and mixtures of copper and beryllium which have considerably lower melting points than the temperatures used in sintering common iron and steel powder mixtures and these beryllium bronzes can therefore be infiltrated at temperatures considerably below the upper limit of the range of the preferred sintering temperatures.

Metal powder for the production of a sintered support body according to the invention can be mixed with suitable binding or cohesive agents to a mouldable mass according to well-known techniques for the production of sintered articles, and as already mentioned the mass can be applied directly onto the pattern. A compression

can be brought about by pressure or for example by ultra sound vibration.

A metal powder mass can be "loosely" sintered onto a pattern and then a metal, such as copper, beryllium copper, tin, zinc, aluminium etc. or mixtures thereof can be incorporated with the loosely sintered body. However, non-metallic materials are also conceivable, for instance enamel or ceramic material. The metallic or non-metallic material can be infiltrated by melting or otherwise in such a manner that the material directly, or at a subsequent heat treatment, reaches the shaping surface and seals the future shaping surface of the sintered body. The shaped body is then separated from the pattern.

Coarse or fine-grained metal powder imparts to the sintered material greater or smaller hollows (pores). If a very fine-grained metal powder is chosen the total pore volume of the sintered body will be relatively small and it is then possible without greater economical disadvantages to use as an alternative to copper and relatively cheap copper alloys as expensive a metal as beryllium copper which imparts to the sintered body satisfactory strength and can be infiltrated and hardened at a relatively low temperature.

Alternatively, a loosely sintered support body can be sealed and reinforced with enamel or ceramic material by immersion (under vacuum) in a slurry or slip and by subsequent heat treatment or baking of the material thus incorporated therewith.

As a further alternative method the pattern surface is first covered with a mouldable enamel mass on which the body of mouldable sinterable material is placed and the enamel is baked and the sinterable material sintered simultaneously so that the enamel is bonded to the supporting body thus formed and infiltrates it. If desired the support body can also be infiltrated by a melted metal or a liquid enamel before or during or after sintering.

It has been mentioned in the foregoing that several different substances can be used to fill out the pores of the sintered support body, it being possible to use such substances as have a low heat expansion coefficient, whereby the dimensional reduction of the sintered body, when the temperature thereof is lowered from the sintering temperature to a lower temperature, can be prevented from progressing as far as it would normally do if the body consisted only of the sintered material. For this purpose, copper and beryllium bronze, respectively, has been mentioned as a particularly suitable metal and metal alloy. Said metal or metal alloy is extraordinarily well suited since a preferred metal powder mixture consists of iron powder with a small

addition of carbon (graphite) and copper. Sintering can be effected at about 1120°C or less and yields a sintered body of very high strength. The copper addition, however, has a tendency of increasing grain growth and to eliminate this problem the powder mixture should also contain the addition of nickel.

A preferred composition for producing the sintered support body according to the invention consists of sponge iron powder of small particle size and having an addition of up to 5% by weight of copper, up to 5% weight of nickel and 0.35-0.65% by weight of graphite.

Experiments have shown that the tensile strength increases with increasing copper content and nickel content at any carbon level and that copper has the greatest influence. However, by copper addition alone the grain growth increases on sintering and it is therefore advantageous to combine copper with nickel, whereby zero growth is attainable. The greatest strength at zero growth has been obtained at the following percentages: 4.0% nickel, 2.5% copper and 0.6% graphite. The reinforcing effect of nickel with this carbon content is limited but can be increased by addition of a small amount of molybdenum to counteract the austenite retention effect. With a partially pre-alloyed iron powder having a carbon content of 0.6%, 4.0% nickel, 1.5% copper and 0.5% molybdenum and at a sintering temperature of 1120°C there was obtained a tensile strength of 750 N/mm², which is a very satisfactory value.

The invention makes it possible to produce in a simple manner forming tools with heat resistant strong support bodies and with forming surfaces which very exactly reproduce the contours of the patterns used. The invention makes it also possible to produce forming tools which are sufficiently heat resistant to the temperatures that may occur in various plastic shaping operations and are sufficiently strong to resist the prevailing pressures, for instance for sheet metal pressing and pressure moulding of plastics. The tools produced in accordance with the invention are in respect of their properties almost comparable with the metal moulds produced by machining in a conventional manner, although the cost of production is only a fraction of the cost of the conventionally produced metal tools.

WHAT WE CLAIM IS:

1. A method of producing a forming tool as herein defined having a forming surface which includes using a pattern of a material capable of resisting a predetermined temperature and having a pattern surface which forms a negative picture of said forming surface, forming a body of mouldable sinterable material in contact with said pattern surface, said mouldable



can be brought about by pressure or for example by ultra sound vibration.

A metal powder mass can be "loosely" sintered onto a pattern and then a metal, such as copper, beryllium copper, tin, zinc, aluminium etc. or mixtures thereof can be incorporated with the loosely sintered body. However, non-metallic materials are also conceivable, for instance enamel or ceramic material. The metallic or non-metallic material can be infiltrated by melting or otherwise in such a manner that the material reaches the shaping surface and seals the future shaping surface of the sintered body. The shaped body is then separated from the pattern.

Coarse or fine-grained metal powder imparts to the sintered material greater or smaller hollows (pores). If a very fine-grained metal powder is chosen the total pore volume of the sintered body will be relatively small and it is then possible without greater economical disadvantages to use as an alternative to copper and relatively cheap copper alloys as expensive a metal as beryllium copper which imparts to the sintered body satisfactory strength and can be infiltrated and hardened at a relatively low temperature.

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As a further alternative method the pattern surface is first covered with a mouldable enamel mass on which the body of mouldable sinterable material is placed and the enamel is baked and the sinterable material sintered simultaneously so that the enamel is bonded to the supporting body thus formed and infiltrates it. If desired the support body can also be infiltrated by a melted metal or a liquid enamel before or during or after sintering.

It has been mentioned in the foregoing that several different substances can be used to fill out the pores of the sintered support body, it being possible to use such substances as have a low heat expansion coefficient, whereby the dimensional reduction of the sintered body, when the temperature thereof is lowered from the sintering temperature to a lower temperature, can be prevented from progressing as far as it would normally do if the body consisted only of the sintered material. For this purpose, copper and beryllium bronze, respectively, has been mentioned as a particularly suitable metal and metal alloy. Said metal or metal alloy is extraordinarily well suited since a preferred metal powder mixture consists of iron powder with a small

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WHAT WE CLAIM IS:

1. A method of producing a forming tool as herein defined having a forming surface which includes using a pattern of a material capable of resisting a predetermined temperature and having a pattern surface which forms a negative picture of said forming surface, forming a body of mouldable sinterable material in contact with said pattern surface, said mouldable

material being sinterable at a sintering temperature which is lower than said predetermined temperature and which before being sintered can be brought into a relatively easily shapable condition and which, when sintered, will form a relatively porous sintered support body, sintering said body when still in contact with said pattern surface before, during or after infiltrating and filling the pores of said body, at least over a portion thereof adjacent said pattern surface, with an infiltrating material which is either solid and is caused to become liquid and flow by an increased temperature below the said sintering temperature and which solidifies when cooled, or a material which is liquid on being infiltrated and is caused to solidify by baking at a temperature below the sintering temperature, and causing said infiltrating material when liquid, to penetrate into the pores of said forming surface in contact with said pattern surface and also to reach said pattern surface and to be formed thereby when solidified.

2. A method as claimed in claim 1 which includes using an iron-based metal powder for the body and a metal or metal alloy of lower melting point than the temperature chosen for the sintering operation for the infiltrating material.

3. A method as claimed in claim 1 or claim 2 which includes using a metal powder mixture which is substantially iron and contains an addition of copper for the body.

4. A method as claimed in claim 3 which includes an addition of nickel in the metal powder mixture.

5. A method as claimed in claim 3 or claim 4 which includes a proportion of molybdenum in the metal powder mixture.

6. A method as claimed in any one of the claims 3, 4 or 5 which includes a proportion of carbon in the metal powder mixture.

7. A method as claimed in claim 6 which includes forming said body by a sinterable metal powder which comprises an iron based powder containing 0.35-0.65% by weight of carbon, up to 5% by weight of copper, up to 5% by weight nickel and, optionally up to 0.5% by weight molybdenum.

8. A method as claimed in any one of the preceding claims and which the infiltrating material comprises or includes, copper, beryllium copper, bronze, beryllium bronze and/or alloys of copper or beryllium, or a mixture of two or more of such metals and/or zinc and/or aluminium.

9. A method as claimed in any one of the preceding claims which includes pre-sintering said body, infiltrating with the infiltrating material and then re-sintering.

10. A method as claimed in claims 1-9 which includes using an iron base metal

powder as the sintering material said sintering of the body and said infiltration being performed simultaneously.

11. A method as claimed in claim 10 which includes further heat treating the body after the sintering operation for hardening said body.

12. A method as claimed in any one of the preceding claims which includes using enamel or a ceramic material as the infiltration material.

13. A method as claimed in claim 12 which includes using a ceramic slurry for the infiltrating material.

14. A method as claimed in any one of the preceding claims in which said sinterable material includes a fine grain metal powder which before sintering is cold-worked so that the grains are deformed and brought into a state of stress which is released at the sintering process.

15. A method as claimed in claims 12 or 13 in which the pattern surface is first covered with a mouldable enamel mass on which the body of mouldable sinterable material is placed and the enamel is baked and the sinterable material sintered simultaneously so that the enamel is bonded to the supporting body thus formed and infiltrates it.

16. A method as claimed in claim 15 in which the support body is also infiltrated by a melted metal or a liquid enamel before or during or after sintering.

17. A method as claimed in claims 1-6 and claim 9 which includes sintering the body shaped from a metal powder mixture at a temperature and for a time which are selected so that an initial bond of the metal powder grains is attained, lowering the temperature and calculating the volume reduction after sintering, selecting a suitable volume compensating or stabilising infiltration material on the basis of said calculation, and then increasing the temperature to a level suitable for volume compensation or stabilising infiltration of the body, and carrying out the infiltration with the selected material.

18. A method of producing a forming tool substantially as described herein.

19. A forming tool made according to the method set forth in any one of the preceding claims.

20. A forming tool as claimed in claim 19 and substantially as described herein.

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