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POOK, Siew Fei [SG/SG]; Blk 6B Boon Tiong Road,
#11-49, Singapore 165006 (SG).

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(74) Agent: **CALLINAN, Keith, William**; Lloyd Wise, Tan-
jong Pagar, P.O. Box 636, Singapore 910816 (SG).

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(71) Applicant (*for all designated States except US*):
**AGENCY FOR SCIENCE, TECHNOLOGY AND
RESEARCH** [SG/SG]; 30 Biopolis Street, #09-02 Matrix,
Singapore 138671 (SG).

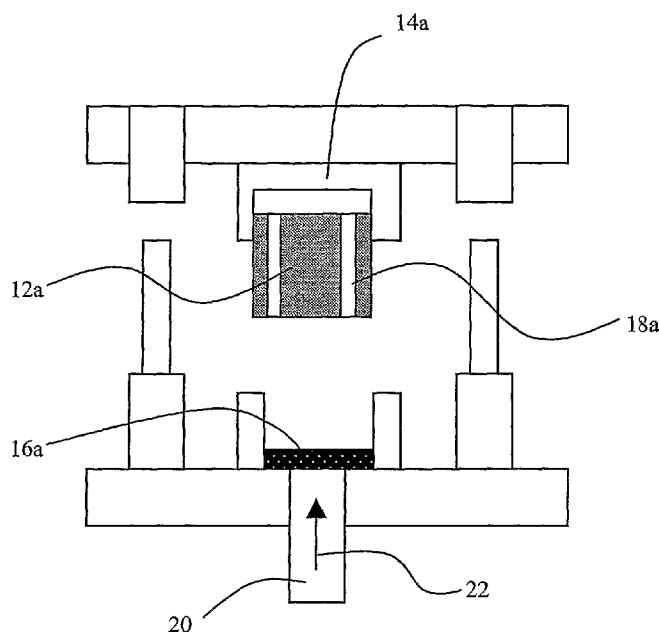
(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **MURALI, Saranga-
pani** [IN/SG]; Blk 363 Yishun Ring Road #08-1560,
Singapore 760363 (SG). **YONG, Ming Shyan, John**
[SG/SG]; Blk 685A Jurong West Street 64, #09-155,
Singapore 641685 (SG). **HO, Meng Kwong** [SG/SG]; Blk
199-D, Kim Tian Road, #26-214, Singapore 164119 (SG).

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[Continued on next page]

(54) Title: LIQUID FORGED ARTICLE



(57) Abstract: The present invention relates to articles formed by liquid forging, particularly to articles having through holes filled with a molten metal. More particularly, it relates to an article having high aspect ratio cavities wherein said cavities are filled with a metal by liquid forging. The invention also relates to a method of forming an article, the method comprising: (a) providing an article having at least one cavity in a mold; (b) providing an at least partially molten metal for filling the at least one cavity; (c) closing the mold to allow pressurized contact of the article with the metal; and (d) applying pressure on the molten metal such that the molten metal fills the at least one cavity.

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Declaration under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report*

TITLE

Liquid Forged Article

FIELD OF THE INVENTION

This invention relates to articles formed by liquid forging, particularly to articles having through holes filled with a molten metal.

BACKGROUND OF THE INVENTION

Articles such as motor rotors are conventionally made by die casting a metal such as aluminium (Al) into inserts having long through holes with small diameters.

Although copper (Cu) provides better conductive properties than Al, die casting Cu at around 1200°C to 1300 with inserts is not ideal because of the high melting point of Cu which shortens the lifespan of a conventional die made of H13 alloy. Moreover, porosity in the article is inevitable with die casting.

SUMMARY OF THE INVENTION

According to one aspect, there is provided an article having high aspect ratio cavities wherein said cavities are filled with a metal by liquid forging. The metal may be selected from the group consisting of: Al and Cu. The high aspect ratio cavities may be long through holes. The holes may be 20-60 mm in length and at least 4 mm in diameter. The liquid forging may be selected from the group consisting of: counter gravity liquid forging, gravity assisted liquid forging and horizontal flow liquid forging. Die tools may be made of materials selected from the group consisting of: H13 alloy, Mo, W and Ni - based alloys, and carbides of Si, W and B.

According to another aspect, there is provided a method of forming an article, the method comprising providing an article having at least one cavity in a mold, providing an at least partially molten metal for filling the at least one cavity, closing the mold to allow pressurized contact of the article with the metal, and applying pressure on the molten

metal such that the molten metal fills the at least one cavity. The molten metal may fill the at least one cavity by flowing either horizontally or vertically into the cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the present invention may be fully understood and readily put into practical effect, there shall now be described by way of non-limitative example only preferred embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

In the drawings:

Fig. 1 is a schematic front view of counter gravity liquid forging in accordance with one embodiment of the invention;

Fig. 2 is a schematic front view of gravity assisted liquid forging in accordance with a second embodiment of the invention; and

Fig. 3 is a schematic front view of horizontal flow liquid forging in accordance with a third embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to one aspect, there is provided an article comprising an insert having long through holes filled with a metal, such as a motor rotor. The metal may be Al or Cu. The cavities are filled by liquid forging of the metal to produce articles with low porosity, making it inexpensive and suitable for mass production.

As shown in Fig. 1, the article 12a is placed in a mold 14a, ready for molten metal 16a to flow through the cavities 18a. When the mold 14a is closed, pressure builds within the molten metal 16a and flow upwards through the cavities. The article is ejected using the pin 20, as depicted by arrow 22.

Another embodiment is shown in Fig. 2, where liquid forging is gravity assisted. In this embodiment, molten metal 16b is poured on top of the insert 12b. When the mold 14b is

closed, the molten metal 16b flows into the cavities 18b under pressure exerted by the punch 24, as shown by arrow 26, as well as by the pull of gravity.

Fig. 3 shows a horizontal flow liquid forging arrangement, wherein the molten metal 16c is to flow horizontally into the cavities 18c when the plunger 28 is pushed, as shown by arrow 30.

The cavities 18a, 18b, 18c can range in length from 20-60 mm and have a diameter of at least 4 mm. Wall thickness between adjacent cavities or holes can range from 300 μm to several centimeters.

Die tools for liquid forging of Al are made of H13 alloy. For liquid forging of Cu, die material is selected from the group consisting of: molybdenum (Mo), tungsten (W) and nickel (Ni) based alloys, and carbides of silicon (Si), tungsten (W) and boron (B). The die materials principally must have an elevated temperature strength, thermal shock resistance and hardness of about 40 HRC for longer die life. For Cu, standard liquid melt treatment is adopted.

Whilst there has been described in the foregoing description a preferred embodiment of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention. For example, other metals than Al and Cu can be used depending on the article to be formed. The method can also be used on inserts having cavities of other sizes and geometries.

CLAIMS

1. An article having high aspect ratio cavities wherein said cavities are filled with a metal by liquid forging.
2. The article according to claim 1, wherein the metal is selected from the group consisting of: Al and Cu.
3. The article of claim 1 or 2, wherein the high aspect ratio cavities are long through holes.
4. The article of any one of the preceding claims, wherein the holes are 20-60 mm in length.
5. The article of any one of the preceding claims, wherein the holes are at least 4 mm in diameter.
6. The article of any one of the preceding claims, wherein the liquid forging is selected from the group consisting of: counter gravity liquid forging, gravity assisted liquid forging and horizontal flow liquid forging.
7. The article of any one of the preceding claims, wherein die tools are made of materials selected from the group consisting of: H13 alloy, Mo, W and Ni -based alloys, and carbides of Si, W and B.
8. A method of forming an article, the method comprising:
 - a. providing an article having at least one cavity in a mold;
 - b. providing an at least partially molten metal for filling the at least one cavity;
 - c. closing the mold to allow pressurized contact of the article with the metal; and
 - d. applying pressure on the molten metal such that the molten metal fills the at least one cavity.
9. The method of claim 8, wherein the molten metal fills the at least one cavity by flowing vertically into the cavity.
10. The method of claim 8, wherein the molten metal fills the at least one cavity by flowing horizontally into the cavity.

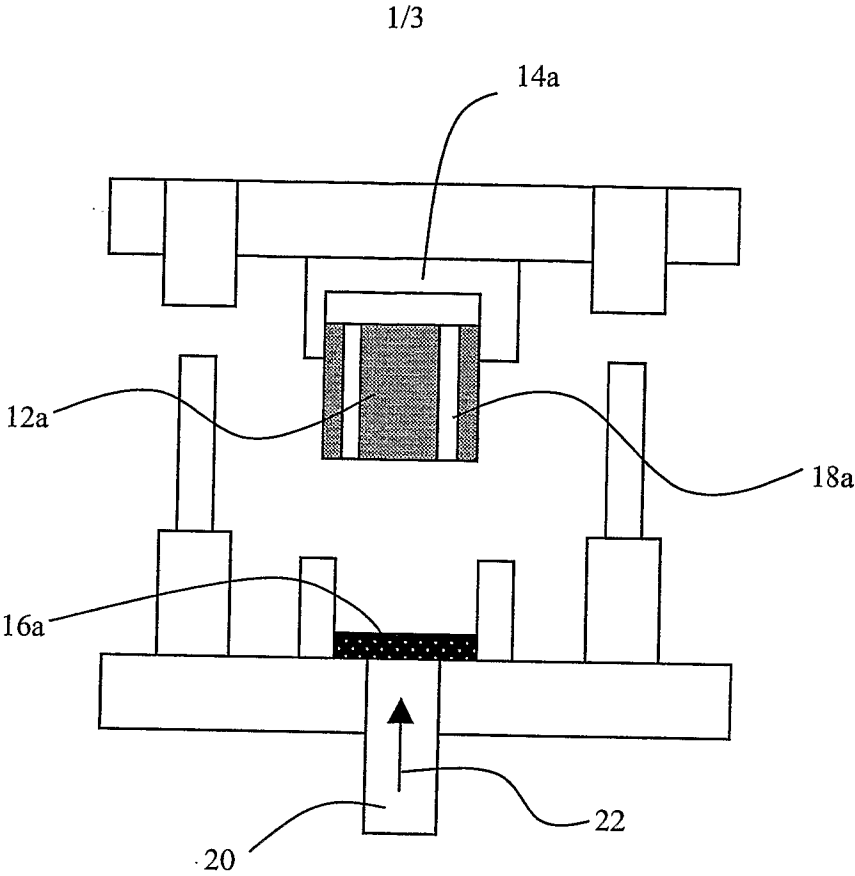


Fig. 1

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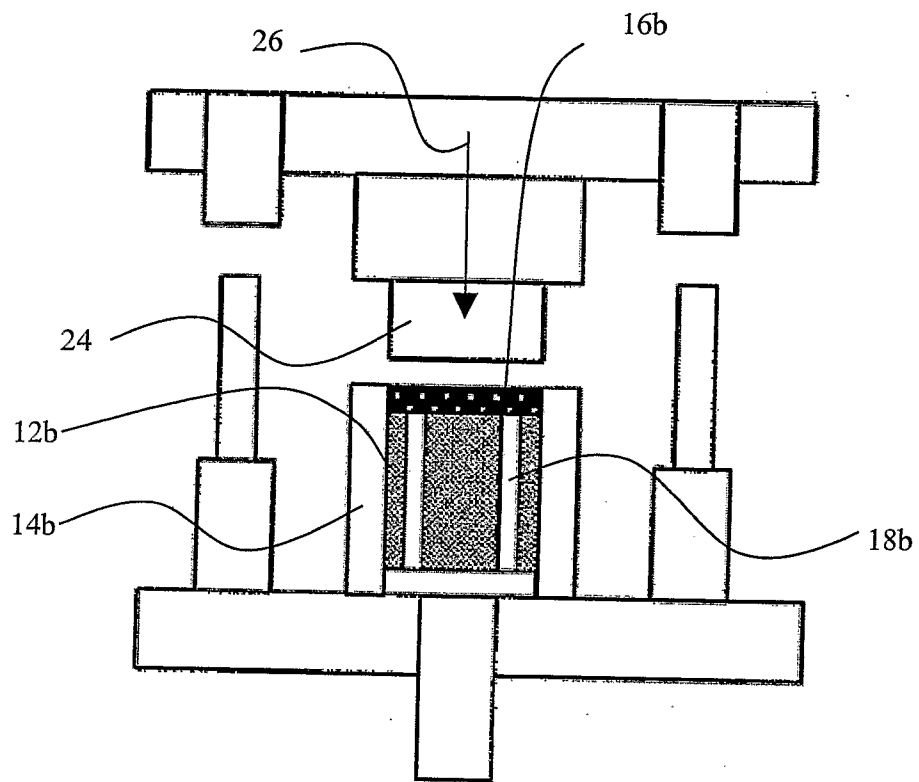


Fig. 2

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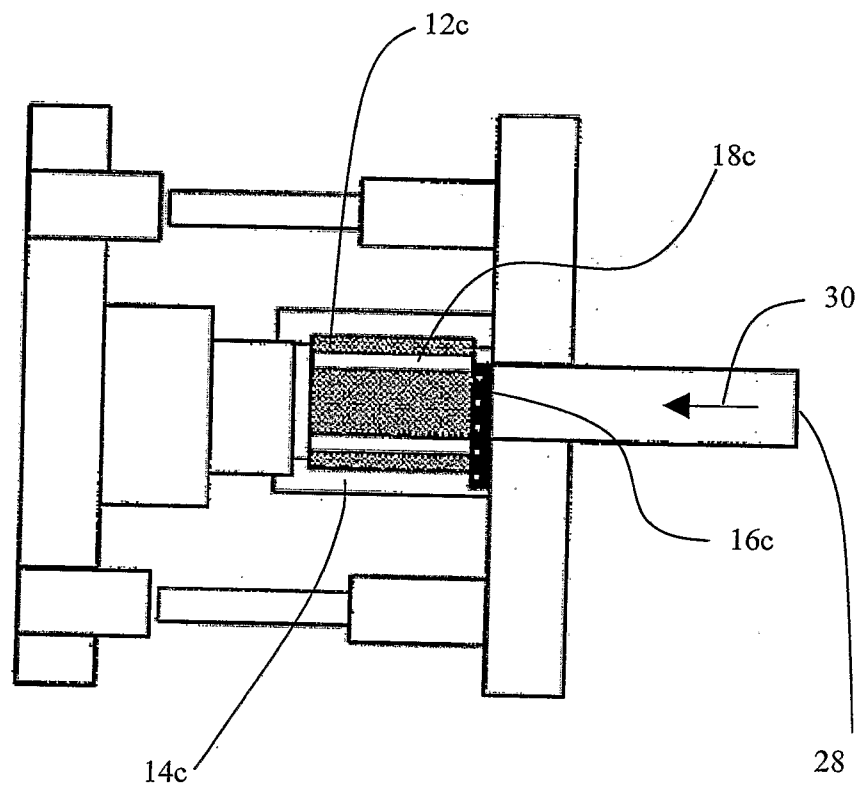


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER Int. Cl. B22D 19/00 (2006.01), B22D 27/09 (2006.01) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DWPI; - B22D 19/IC + Keywords ESPACE, Google Patents and Keywords (pressur+, forc+, plung+, piston+, forg+, copper, alumin+, cavit+, hole+, rotor+, stator+, die+, alloy+, carbid+)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6786272 B2 (COWIE ET AL.) 7 September 2004 Whole document	1 - 10
X	US 5067550 A (MAEKAWA ET AL.) 26 November 1991 Whole document	1 - 10
A	US 3613768 A (NAGOYA-SHI) 19 October 1971 Whole document	1 - 10
☐ Further documents are listed in the continuation of Box C ☒ See patent family annex		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
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Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. +61 2 6283 7999		Authorized officer Prasanta Chattopadhyay AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : (02) 6225 6165

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2008/000012

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Supplemental Box

(To be used when the space in any of Boxes I to IV is not sufficient)

Continuation of Box No: III

1. Claims 1 – 7 are directed to an article having high aspect ratio cavities filled with a metal from the group consisting of Al and Cu by liquid forging. It is considered that the high aspect ratio cavities filled with metal by liquid forging constitute a first technical feature.
2. Claims 8 – 10 directed to a method of forming an article comprising of providing at least one cavity in a mold, providing an at least partially molten metal for filling said cavity, closing the mold and applying pressure to the molten metal to fill the at least one cavity. It is considered that the article with one cavity in a mold, the closing of the mold and the applying of pressure on the molten metal constitutes a second technical feature.

Since the abovementioned groups of claims do not share the technical features identified, a “technical relationship” between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the application does not relate to one invention or to a single inventive concept *a priori*.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2008/000012

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
US 6786272	AU 27227/02	US 2002062941	WO 0243903
US 5067550	JP 2237447	JP 3159546	JP 3159547
US 3613768	DE 1904910	GB 1257963	
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			
END OF ANNEX			