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(54) Title: METHOD FOR MAKING A MOULD WITH A 3D PRINTER

(57) Abstract: Method of manufacturing a moulding tool (1), comprising at least the following steps: a) Providing a 3D printer (2) and b) Manufacturing a moulding tool body (3) with the 3D printer (2), wherein at least one heat pipe (4) is formed during the manufacture of the moulding tool body (3).

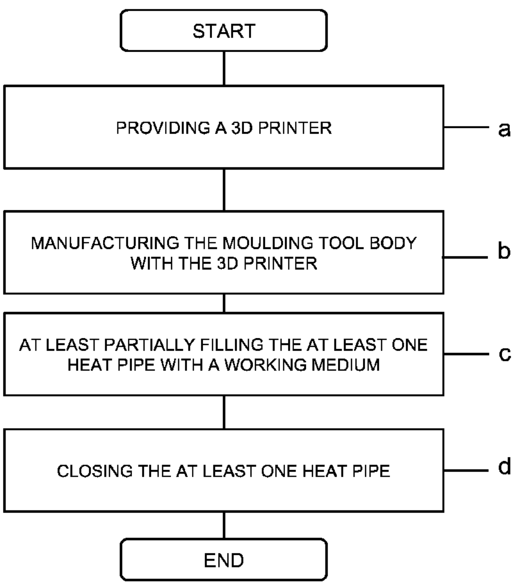

Fig. 1

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Method for making a mould with a 3D printer

TECHNICAL FIELD

The present disclosure relates to a method for manufacturing a moulding tool. Such moulding tools are particularly useful as casting moulds when casting workpieces.

BACKGROUND ART

When casting workpieces, a liquid melt of a material, such as metal or plastic, is regularly poured or (under high pressure) injected into the cast mould. The cast mould may consist of one or more moulding tools and has at least one cavity for the liquid melt. The liquid melt solidifies in the cavity and takes on an inner contour of the cavity as its outer shape. In order to achieve high productivity in casting, moulding tools may be cooled so that the cooling time of the workpieces is reduced. For this purpose, for example, cooling channels may be formed in the moulding tools through which a working medium, such as water, flows during casting. In order to improve the cooling of the workpieces and the forming tools, it has also already been suggested that heat pipes be inserted into forming tools. Heat pipes allow a high heat flow density by using the evaporation heat of a working medium, so that large amounts of heat may be transported away from the workpieces and forming tools.

SUMMARY

Nevertheless, the productivity of casting processes, especially for the mass production of workpieces, is not sufficient. The object of the disclosure is therefore to solve, at least partially, the problems described with respect to the state of the art and, in particular, to specify a method of manufacturing a moulding tool by which the productivity of casting processes may be further increased.

This object is solved with a method according to the features of the independent claim. Further advantageous embodiments of the invention are indicated in the dependent claims. It should be noted that the features individually listed in the dependent claims can be combined in any technologically meaningful way and define further embodiments of the invention. In addition, the features individually indicated in the claims are specified and explained in more detail in the description, and further preferred embodiments of the invention are presented.

A method for the production of a moulding tool contributes to this which comprises at least the following steps:

a) Providing a 3D printer, and
b) Manufacturing a moulding tool body with a 3D printer, wherein at least one heat pipe is formed during manufacture of the moulding tool body.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1: is a flowchart that illustrates a sequence of the method described here;
Fig. 2 the production of a moulding tool with a 3D printer; and
Fig. 3: a section of a moulding tool body of the moulding tool in an enlarged view.

DESCRIPTION OF EMBODIMENTS

The method is used to produce a moulding tool comprising a moulding tool body. The moulding tool is used in particular as a casting mould, part of a casting mould, injection moulding tool or casting core for casting workpieces. In particular, the moulding tool is a permanent mould that may be used several times. However, the moulding tool may also be a so-called lost mould, which is destroyed when the workpiece is cast or when the workpiece is removed from the mould. In particular, the moulding tool may be used as an injection mould for plastic injection moulding. For this purpose, the moulding tool may be connected to an injection moulding machine. Furthermore, the moulding tool may have at least one inlet for a liquid melt of a material such as metal or plastic. In addition, the moulding tool may have at least one (hollow) casting chamber into which the liquid melt may be poured or (at high pressure) injected. For this purpose, the at least one inlet for the liquid melt may open into the at least one casting chamber. In particular, the at least one casting chamber is at least partially limited by a working surface of the moulding tool body. After casting, the liquid melt solidifies in the casting chamber and at least partially assumes the shape of a surface contour of the working surface of the moulding tool body.

For the production of the moulding tool, as shown Fig. 1, a 3D printer is first provided in step a). In particular, a 3D printer is a device for additive manufacturing. In additive manufacturing, the material used to produce a three-dimensional (3D) object is applied layer by layer. The three-dimensional object to be produced may be built up layer by layer from one or more liquid or solid materials under computer control. The shape or geometry of the three-dimensional object to be produced may be specified by CAD data, for example. Materials used for 3D printing may be plastics, resins, ceramics and/or metals. Metal, such as steel, copper or a copper alloy, is preferred for the production of the moulding tool.

In a step b), the moulding tool body of the moulding tool is produced or printed with the 3D printer. When the moulding tool body is manufactured or printed, at least one heat pipe (possibly not yet provided with coolant or not yet completely closed) is formed. This means in particular that the geometric structure of the at least one heat pipe is (at least partially) printed directly into the moulding tool body during the production of moulding tool body. The at least one heat pipe is a heat exchanger which allows a high heat flow density by using the heat of evaporation of a working medium. This allows large amounts of heat to be transported through at least one heat pipe. The at least one heat pipe is designed in particular in the manner of a so-called "heat pipe" [technical term]. The at least one heat pipe comprises in particular an evaporation zone in which, when casting workpieces, the coolant of the at least one heat pipe evaporates when it reaches its boiling temperature. The temperature of the moulding tool body does not increase any further because the supplied energy is converted into evaporation heat. As the working medium evaporates, the pressure in the evaporation zone increases, so that the evaporated working medium is distributed over an entire volume of the heat pipe. The at least one heat pipe may have a cooling zone in which the temperature of the working medium may fall below the boiling point of the working medium. For this purpose, the at least one heat pipe may dissipate the heat especially to an environment. Furthermore, the at least one heat pipe in its cooling zone may be connected or connected to a heat sink or condenser, for example. The evaporated working medium condenses in the cooling zone and releases the absorbed thermal energy as condensation heat. The liquid working medium may then be led back to the evaporation zone by capillary forces. The working medium is selected depending on the working temperature or the range of the working temperature of the moulding tool. The working temperature of the moulding tool is in particular the temperature or temperature range to which the moulding tool heats up when casting workpieces. In particular, the working medium has a boiling temperature which is within the range of the working temperature of the moulding tool. The working medium (at working temperature) may be a fluid in particular. In particular, the working medium is water, mercury, potassium and/or sodium.

The geometrical structures of the at least one (capillary) heat pipe, which are produced in step b) by the 3D printer, are in particular at least one (integrated) vapour channel and at least one (integrated) condensate channel. The at least one vapour channel and the at least one condensate channel may in particular be provided together or in combination. In other words, this may mean that the at least one vapour channel and the at least one condensate channel are ”in one body”. The at least one vapour channel is in particular at least one channel through which the evaporated working medium may flow from the evaporation zone to the cooling zone. The at least one condensate channel is in particular at least one channel through which the condensed working medium may flow from the cooling zone back to the evaporation zone. When the moulding tool body is produced in step b), a single heat pipe, a plurality of heat pipes or a multiplicity of heat pipes may be formed. The at least one heat pipe is formed especially in the area of the working surface of the moulding tool body. Furthermore, the at least one heat pipe, the plurality of heat pipes or the multiplicity of heat pipes may be formed (only) in a partial area of the working surface of the moulding tool body, for example to exclude certain areas of the working surface from cooling. For example, the area of the at least one inlet for the melt may be excluded from the formation of heat pipes. Furthermore, the at least one heat pipe is formed as close as possible to the working surface of the moulding tool body. Due to the formation of the at least one heat pipe during the production of the moulding tool body by the 3D printer, the at least one heat pipe is not a separate component. The at least one heat pipe is instead, in particular, made of the same material as the rest of the moulding tool body and/or integrally formed with the moulding tool body. This increases the heat transfer from the cast workpiece via the moulding tool body to the at least one heat pipe, thus accelerating the cooling time of the workpieces. By accelerating the cooling of the workpieces, the cycle times for casting or plastic injection moulding may be reduced, thus increasing productivity. Furthermore, the wear of the working surface may be reduced by a targeted cooling, thus increasing the service life of the moulding tool. In addition, local material characteristics in the produced workpiece may be adjusted through selective cooling. In addition, workpieces with the same quality may be produced over a longer period of time.

It is obvious that step b) may be executed several times successively once step a) has been executed once.

The at least one heat pipe may be at least partially formed with a non-straight shape. The at least one heat pipe may run in particular through areas where a particularly high heat input may be expected. The non-straight shape is particularly easy to produce with the 3D printer.

The at least one heat pipe may be configured in such a way that it at least partially follows a surface contour of a working surface of the moulding tool body. The at least one heat pipe may in particular be provided in such a way that an evaporation zone of the at least one heat pipe is at least partially (substantially) at an equal distance from the working surface.

The at least one heat pipe may be formed so that it extends at least partially at a distance of less than 5 mm (millimetres) from a working surface of the moulding tool body. Preferably the distance is less than 3 mm, preferably 1 mm.

An open-pored structure may be formed at least partially between the at least one heat pipe and a working surface of the moulding tool body. In the case of the open-pored structure, for example, it may be an area of the moulding tool body that is porous in design. The working medium may enter the open-pored structure from the heat pipe and evaporate there.

After step b), the at least one heat pipe may be at least partially filled with a working medium in a step c). This may mean that the at least one heat pipe in step b) is not completely closed.

After step c) at least one heat pipe may be closed in step d). The closing of at least one heat pipe may be done by the 3D printer or manually, for example by a welding process.

The at least one heat pipe may have at least one capillary structure. The at least one capillary structure comprises at least one channel, preferably a multiplicity of channels. A diameter of the channels is dimensioned in such a way that the working medium may be led from the cooling zone to the evaporation zone as a result of capillary forces. The at least one capillary structure is in particular at least one condensate channel through which the condensed working medium flows from the cooling zone to the evaporation zone. The at least one capillary structure may completely surround a hollow area or a vapour channel of the at least one heat pipe or be formed (only) between the hollow area or vapour channel and the working surface.

Through the at least one capillary structure, a cooling medium of the at least one heat pipe may be conducted to an evaporation zone of the at least one heat pipe.

The at least one heat pipe may be made of the same material as the moulding tool body.

The use of a moulding tool, produced according to one of the methods described here, is particularly preferred for the manufacture of a sanitary article, such as in particular the housing of a fitting.

The disclosure as well as the technical environment is explained in more detail below using the figures. It should be noted that the figures show a particularly preferred embodiment of the disclosure, but that this is not limited to it. Identical components in the figures are marked with the same reference signs. It shows exemplary and schematic:

Fig. 2 shows a moulding tool 1 in the manner of an injection mould for an injection moulding machine not shown here. Moulding tool 1 comprises a moulding tool body 3, which is shown here in longitudinal section. Moulding tool body 3 was printed by a 3D printer 2 on a metal printing surface 11 and has a casting chamber 12 that may be closed with another moulding tool body 3 or a cover. When casting chamber 12 is closed, molten plastic may be poured or injected under pressure into casting chamber 12 by the injection moulding machine to produce a workpiece (not shown here). The casting chamber 12 is limited by a working surface 6 of the moulding tool body 3. The work surface 6 has a surface contour 5, by which a shape of the workpiece to be produced is at least partially specified. When printing the moulding tool body 3 with the 3D printer 2, a heat pipe 4 was formed in the moulding tool body 3. The heat pipe 4 has an evaporation zone 9, in which the heat pipe 4 follows the surface contour 5 of the working surface 6 of the moulding tool body 3 with a distance 7, which is less than 5 mm in the embodiment shown here. Due to the non-straight course of the surface contour 5, the heat pipe 4 also has a non-straight shape. The heat pipe 4 extends from the evaporation zone 9 to a cooling zone 10, the evaporation zone 9 being formed at a first longitudinal end 13 of the heat pipe 4 and the cooling zone 10 at an opposite second longitudinal end 14 of the heat pipe 4. A working medium located in the heat pipe 4 may be evaporated in the evaporation zone 9 during the production of a workpiece. After evaporation of the working medium, the vaporous working medium may flow from evaporation zone 9 to cooling zone 10, where it may be cooled and condensed. In the area of cooling zone 10, the heat pipe 4 is connected to a heat sink 15 in the embodiment shown here. Thus, heat transferred to the heat pipe 4 through the workpiece during injection moulding and/or during subsequent cooling to the moulding tool body 3 may be transported through the vaporous working medium to the cooling zone 10, where the heat may be transferred to an environment 16. As the heat pipe 4 is formed with a very small distance to the work surface 6, the workpiece may be cooled down particularly quickly. This increases the productivity of the manufacturing process of the workpieces.

Fig. 3 shows an enlarged view of an area 17 of the moulding tool body 3 shown in Fig. 2. In particular, the structure of the heat pipe 4 printed by the 3D printer 2 shown in Fig. 2 may be seen here. In the embodiment shown here, the heat pipe 4 comprises (in its interior) a hollow area 19 or a vapour channel which extends along the heat pipe 4 from the evaporation zone 9 shown in Fig. 2 to the cooling zone 10. The hollow area 19 is (at least partially) surrounded by a capillary structure 8 or by at least one condensate channel, which also extends from the evaporation zone 9 shown in Fig. 2 to the cooling zone 10. In the evaporation zone 9, an open-pored structure 18 was also printed between the heat pipe 4 and the working surface 6 of the moulding tool body 3 when printing the moulding tool body 3. The open-pored structure 18 extends (directly) from the heat pipe 4 to the working surface 6, but the open-pored structure 18 ends before reaching the working surface 6 (e.g. at a distance of less than 3 mm), so that no working medium may escape from the heat pipe 4. After printing the heat pipe 4 and the open-pored structure 18, the heat pipe 4 was partially filled with the working medium and then hermetically sealed. The working medium may enter the open-pored structure 18 from the heat pipe 4 and is heated there when casting workpieces. The heat input through the cast workpiece increases the temperature of the moulding tool body 3 and the working medium until the boiling point of the working medium is reached. When the boiling point is reached, the working medium begins to evaporate in the open-pored structure 18 and/or the evaporation zone 9 of the heat pipe 4. However, the temperature does not rise any further because the thermal energy supplied is converted into heat of evaporation. When evaporating the working medium, thermal energy is thus extracted from working surface 6 due to the evaporation enthalpy of the working medium. As the working medium evaporates, the pressure in the evaporation zone 9 increases, so that the vaporous working medium flows through the hollow area 19 to the cooling zone 10 shown in Fig. 2. In the cooling zone 10 the vaporous working medium condenses and is returned in the liquid aggregate state through the capillary structure 8 as a result of capillary forces to the evaporation zone 9, where it evaporates again.

The present disclosure enables the productivity of casting processes to be increased.

What is claimed is:

1. A method for manufacturing a moulding tool (1), comprising:
   a) Providing a 3D printer (2); and
   b) Manufacturing a moulding tool body (3) with the 3D printer (2), wherein at least one heat pipe (4) is formed during the manufacture of the moulding tool body (3).

2. The method according to Claim 1, wherein the at least one heat pipe (4) is at least partially formed with a non-straight shape.

3. The method according to any one of the preceding claims, wherein the at least one heat pipe (4) is formed in such a way that it at least partially follows a surface contour (5) of a working surface (6) of the moulding tool body (3).

4. The method according to any one of the preceding claims, wherein the at least one heat pipe (4) is formed in such a way that it extends at least partially at a distance (7) from a working surface (6) of the moulding tool body (3) of less than 5 mm.

5. The method according to any one of the preceding claims, wherein an open-pored structure (18) is formed at least partially between the at least one heat pipe (4) and a working surface (6) of the moulding tool body (3).

6. The method according to any one of the preceding claims, wherein after step b) in a step c) the at least one heat pipe (4) is at least partially filled with a working medium.

7. The method according to Claim 6, wherein after step c) in a step d) the at least one heat pipe (4) is closed.

8. The method according to any one of the preceding claims, wherein the at least one heat pipe (4) has at least one capillary structure (8).

9. The method according to Claim 8, wherein a working medium of the at least one heat pipe (4) may be conducted through the at least one capillary structure (8) to an evaporation zone (9) of the at least one heat pipe (4).

10. The method according to any one of the preceding claims, wherein the at least one heat pipe (4) is formed from the same material as the moulding tool body (3).

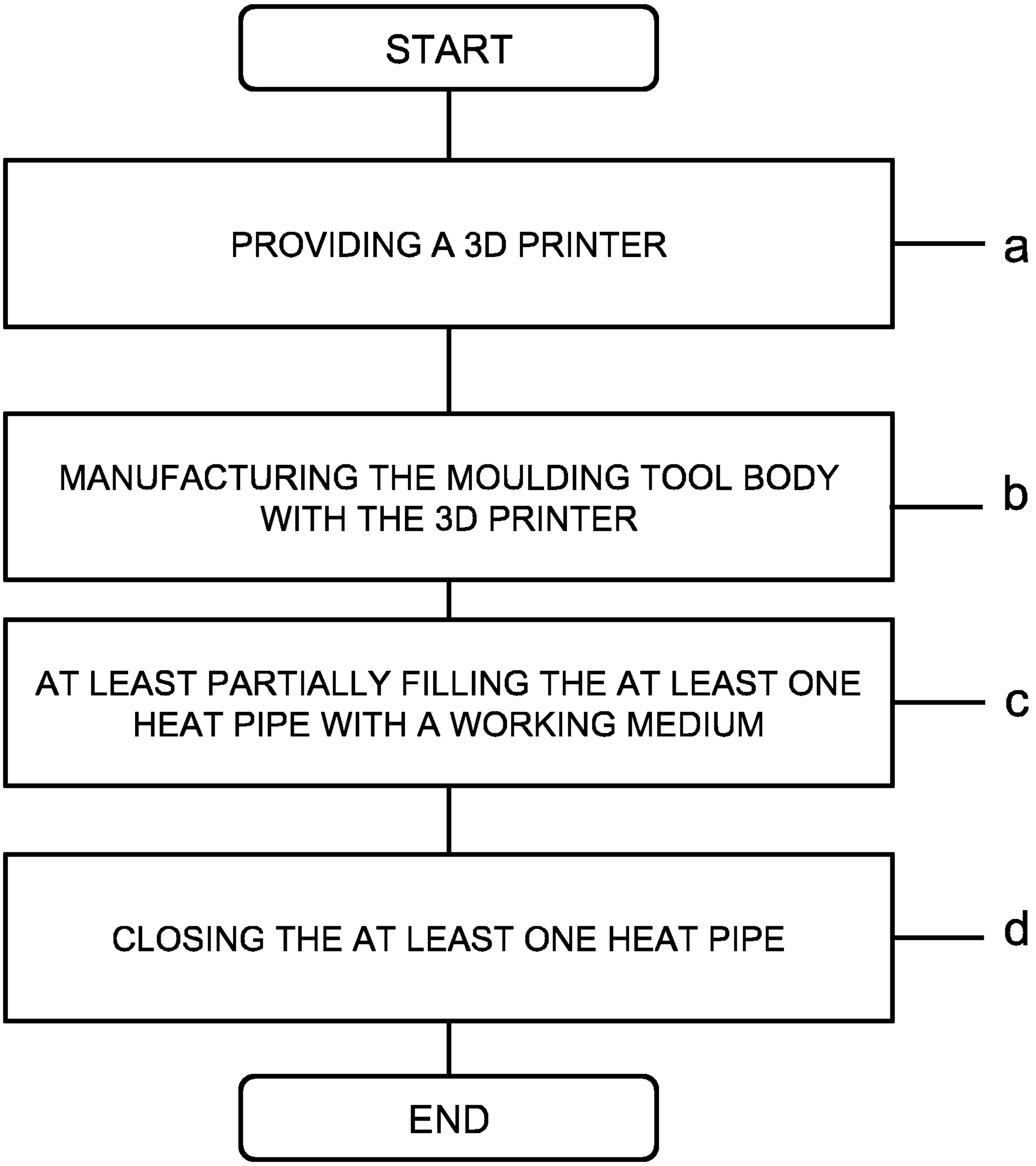
START
PROVIDING A 3D PRINTER
a
MANUFACTURING THE MOULDING TOOL BODY WITH THE 3D PRINTER
b
AT LEAST PARTIALLY FILLING THE AT LEAST ONE HEAT PIPE WITH A WORKING MEDIUM
c
CLOSING THE AT LEAST ONE HEAT PIPE
d
END

Fig. 1

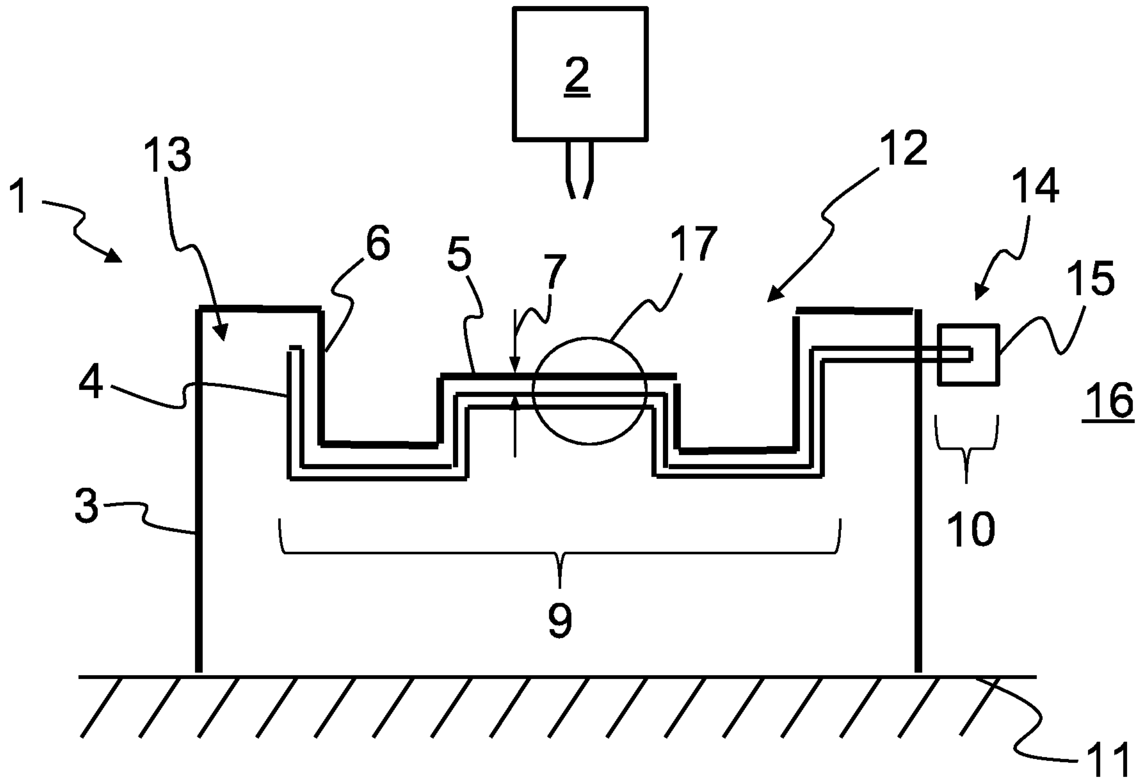

Fig. 2

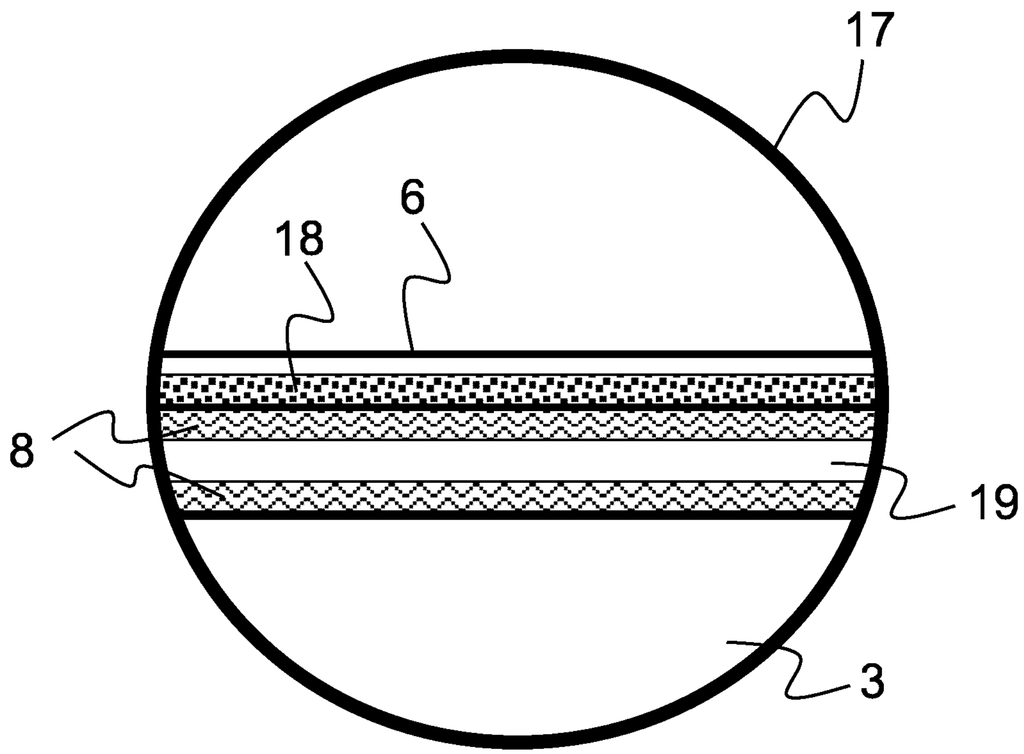

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/058553

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22D17/22 B22F3/00 B28B1/00 B29C64/00
ADD.

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)
B22D B29C C22C B22F B28B

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2003/206820 A1 (KEICHER DAVID M [US] ET AL) 6 November 2003 (2003-11-06) paragraph [0001] paragraph [0022] - paragraph [0026] paragraphs [0066], [0075] - [0077] paragraph [0169] - paragraph [0178] ----- -/--	1-7,10 8,9

[X] Further documents are listed in the continuation of Box C.

[X] 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

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"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

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 June 2020	09/06/2020

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1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DAVOUD JAFARI ET AL: "Metal 3D-printed wick structures for heat pipe application: Capillary performance analysis", APPLIED THERMAL ENGINEERING, vol. 143, 1 October 2018 (2018-10-01), pages 403-414, XP055578443, GB ISSN: 1359-4311, DOI: 10.1016/j.applthermaleng.2018.07.111 abstract page 404, left-hand column, line 36 - page 404, right-hand column, line 39 page 413, left-hand column, line 40 - page 413, right-hand column, line 36 -----	8,9
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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