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(54) METHOD TO INCORPORATE COOLING LINES IN A SPRAY-FORMED ARTICLE

(76) Inventors: **Grigoriy Grinberg**, Sylvania, OH (US); **David Robert Collins**, Saline, MI (US); **Richard L. Allor**, Livonia, MI (US)

Correspondence Address:
BROOKS & KUSHMAN P.C./FGTL
1000 TOWN CENTER
22ND FLOOR
SOUTHFIELD, MI 48075-1238 (US)

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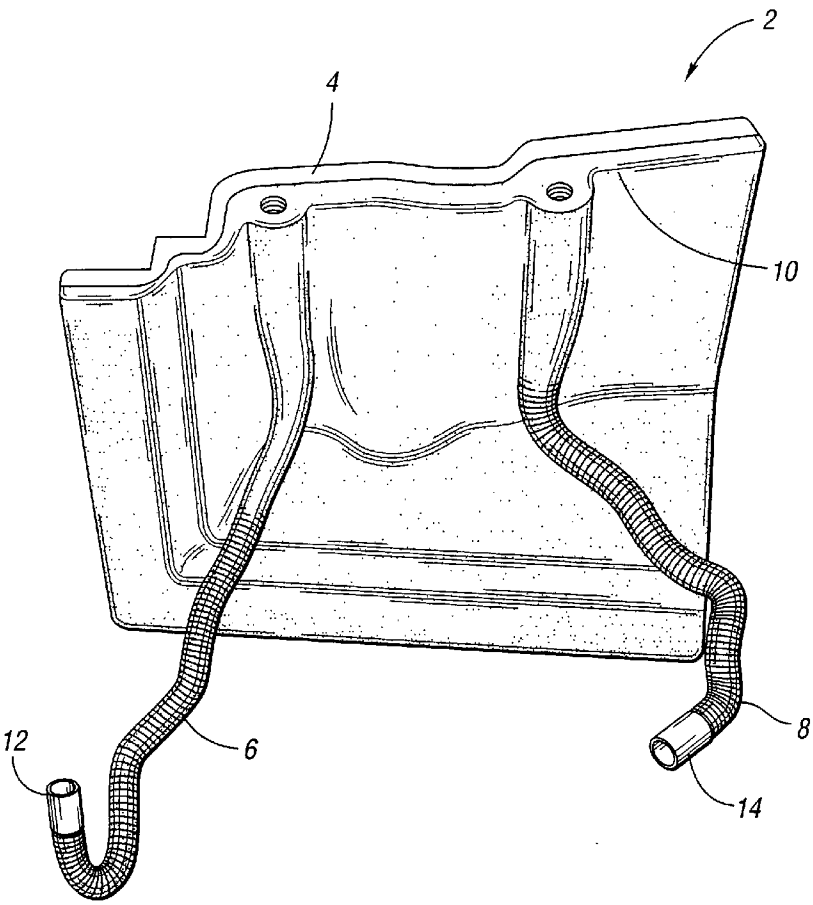
(57) ABSTRACT

At least one aspect of the present invention relates to an improved method of incorporating fluid lines in a spray-formed article. The method comprises forming a first component having a backing surface followed by placing a fluid defining flexible conduit adjacent the backing surface. Next, metal droplets are sprayed over the backing surface to from a metallic adhesion layer. The metal droplets used to form the adhesion layer are sprayed in a sufficient amount that the adhesion layer at least partially encapsulates the flexible conduit whereby the conduit is fastened to the backing surface by the metallic adhesion layer. Also provided by the present invention is an article made in accordance with a method of the invention.



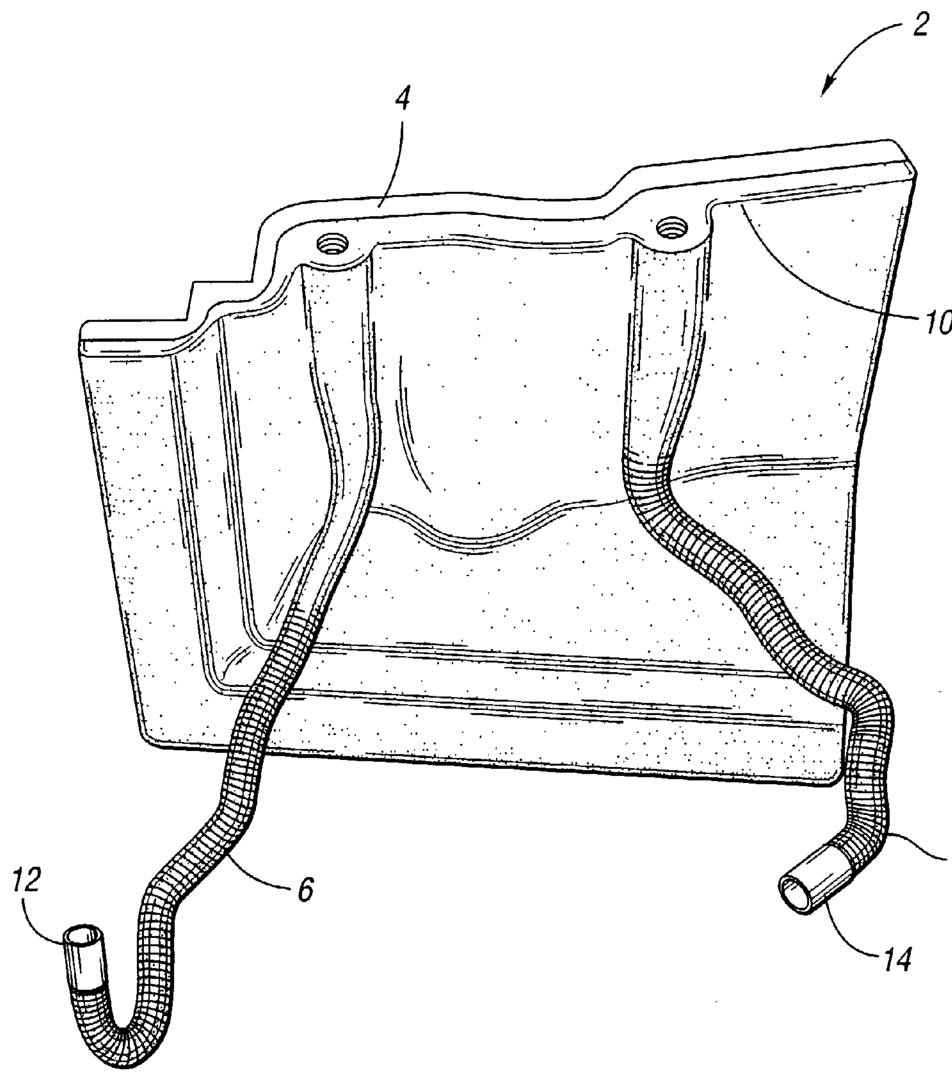


Fig. 1

METHOD TO INCORPORATE COOLING LINES IN A SPRAY-FORMED ARTICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional application Serial No. 60/319,016, filed Nov. 29, 2001.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] In at least one aspect, the present invention relates to the production of at least partially metallic articles with heat transfer channels and, in particular, to at least partially metallic articles with partially embedded cooling lines.

[0004] 2. Background Art

[0005] Many metal manipulating processes utilize tools such as dies, molds, and the like are typically required to operate within a specific temperature range in order to ensure that the operation for which they were designed proceeds smoothly and produces an optimized product. Examples of such processes are plastic injection molding (PIM) techniques where it may be desirable to hold dies at a temperature of, for example, about 100° C. Another illustrative example is high pressure die casting (HPDC) using aluminum alloys, which are preferably operated in a temperature range from about 200° C. to 250° C. In both examples, material from which a part is made is injected at a higher temperature than the mold or die. The mold or die cools the injected material until it becomes substantially solid, after which the product is ejected. In the process of cooling the injected material, the mold or die becomes relatively hotter and must then be allowed to cool (or be artificially cooled) to return to the required operational temperature range.

[0006] To reduce cycle times and, therefore, increase production efficiency, it is preferable to cool mold or dies during or after use by means of in-built heat transfer channels for cooling water to circulate within the mold or die. Typically, cooling channels such as these are made by drilling into the mold or die block during manufacture and fitting connections for the circulation of cooling water or, in some cases, cooling air. The construction of such cooling channels typically involves complex, accurate and expensive drilling and plugging of many channels.

[0007] Although the tooling used in these processes may be made by a number of different processes, rapid production of prototype and production tooling is becoming increasingly important in the automotive industry. Some relatively important uses for prototype and production tooling is stamping, die casting, and molding tools. Currently, small sets of prototype tooling can take from six to eight weeks to fabricate, while large prototype tools can take two to three months to produce. The spray-form process is typically capable of producing tooling in less than one month at a cost that is equal or lower than conventional methods.

[0008] In some spray-forming processes, hot molten metal is sprayed onto a ceramic pattern (i.e., ceramic mold) to form a desired tool. The ceramic pattern is essentially the reverse of the desired tool to be produced. Typically, the ceramic pattern is made by pouring a ceramic slurry onto a master model which is subsequently solidified. This master model may be made using a free form fabrication technique. When solidification is complete, the resulting ceramic pattern is put through a series of heat cycles and becomes the receptor onto which metal is sprayed to form a deposit in the shape of the desired tool. The spray-forming process requires that such a ceramic pattern be made from a material that has excellent dimensional accuracy, superior surface finish, excellent heat transfer and low thermal expansion. A suitable ceramic material is aluminum oxide.

[0009] One typical spray-forming process comprises wire-arc thermal spraying. In a common type of wire-arc spraying, electric current is carried by two electrically conductive, consumable wires with an electric arc forming between the wire tips. A high-velocity gas jet blowing from behind the consumable wire tips strips away the molten metal, which continuously forms as the wires are melted by the electric arc. The high-velocity gas jet breaks up or atomizes the molten metal into relatively fine particles to create a distribution of molten metal droplets. The atomizing gas then accelerates the droplets away from the wire tips towards the ceramic pattern where the molten metal droplets impact the ceramic pattern to incrementally form a deposit in the shape of the desired article.

[0010] The desired article is then removed from the ceramic pattern. The removal is typically accomplished by cutting off the perimeter of the metal deposit with a high pressure water jet, chiseling off the majority of the ceramic pattern and then using a glass bead blaster to remove the residual ceramic from the surface of the desired article. In the case of a tool, the completed tool is then mounted and used to produce parts in conventional stamping, die casting, molding, or other tool-usable processes.

[0011] Although the above process for making a spray-formed article works well, as set forth above, for many applications cooling lines need to be incorporated in the formed tooling. One solution to this problem is provided in U.S. Pat. No. 5,875,830 (the '830 patent) which provides a method of incorporating cooling lines into a tool by placing solid lead lines adjacent to the tool and spraying steel atop the lead lines. The tool is heated to melt and remove the lead leaving behind a channel network that may be used to cool the tool. However, this process is somewhat complicated when complex or extensive cooling lines need to be incorporated. In such instances, it becomes increasing difficult to remove the molten lead because passage may exist that can not be drained by gravity. Additionally, the '830 patent also suggests embedding tubing by spraying molten metal over tubing adjacent to the non-working surface of the tool to form cooling channels in contact with the tool. However, the utilization of such relatively non-flexible tubing requires the use of tube bending equipment and is somewhat limited in the complexity of the cooling network that can be formed. Moreover, the utilization of such tubing limits the size of the cross-section of the tubing that may be used and therefore the amount of cooling attainable. Finally, the '830 patent does not appreciate that straight tubing (i.e., tubing that is not corrugated) does not induce any appreciable turbulence in the fluid flowing through the tubing. Such turbulence is important in improving heat exchange efficiency.

[0012] Accordingly, there exist a need for an improved method to incorporate cooling lines in a spray-formed article that is simple to implement and provides improved heat transfer.

SUMMARY OF THE INVENTION

[0013] At least one aspect of the present invention overcomes at least one of the problems encountered in the prior art by providing an improved method of incorporating fluid lines in a spray-formed article. Specifically, the present invention represents an improvement over U.S. Pat. No. 5,875,830, which is hereby incorporated by reference. The present invention improves the method of forming cooling channels disclosed in this patent by providing a method of forming more complex cooling channels as well as cooling channels within which turbulence in the fluid flowing therein is induced. Such turbulence increases heat exchanges within the spray-formed article. The method of the invention comprises forming a first component having a backing surface followed by placing a fluid defining flexible conduit adjacent the backing surface. Next, metal droplets are sprayed over the backing surface to from a metallic adhesion layer. The metal droplets used to form the adhesion layer are sprayed in a sufficient amount that the adhesion layer at least partially encapsulates the flexible conduit whereby the conduit is fastened to the backing surface by the metallic adhesion layer.

[0014] In another embodiment of the present invention, an article made by the method of the invention is provide. The article comprises a first component having a backing surface; a flexible conduit adjacent the backing surface; and a metallic adhesion layer disposed over the backing surface of the first component. The metallic adhesion layer present in the article of the invention is formed by spraying metal droplets over the backing surface of the first component. Moreover, the flexible conduit is at least partially encapsulated in the metallic adhesion layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1** is a perspective view of a section of an article with encapsulated fluid passages made in accordance with at least one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0016] Reference will now be made in detail to presently preferred compositions or embodiments and methods of the invention, which constitute the best modes of practicing the invention presently known to the inventors.

[0017] In one embodiment of the present application, a method of making an article having fluid passages is provided. Specifically, the disclosed method incorporates cooling lines into a spray-formed article. The method comprises:

[0018] (a) forming a first component having a backing surface;

[0019] (b) placing flexible conduit capable of transporting fluid adjacent the backing surface; and

[0020] (c) spraying metal droplets atop the backing surface to from a metallic adhesion layer. The metal droplets used to form the adhesion layer are sprayed in a sufficient amount that the adhesion layer at least partially encapsulates the flexible conduit whereby the conduit is fastened to the backing surface by the metallic adhesion layer. Preferably, the article is made by the spray-form process. To be more specific, the first component is made by the spray-formed process. In accordance with this process, a model of the finished article is created. This model may be made of a variety of materials such as plastic, wood, metal and ceramics. This model then serves as a pattern for a casting. The casting has a shaping surface that is transferred to the spray-formed component. The casting may be of ceramic or other material such as sand. In certain embodiments, molten metal droplets are directed to the casting to form the first component. Typically, the molten metal droplets and thereby the first component are made from steel. Cold spraying could also be employed. When the finished article is a tool or die, layers of deposited spray metal material form a shell. Thereby, the article made by the method of the present invention, as well as the first component, has a working surface which is the inverse of model. This working surface is the surface that is used to form parts in such processes as molding or die stamping. The first component also has a backing surface. The backing surface does not come in contact with a part that is made by the finished article of the present invention. Moreover, the backing surface is the surface upon which the flexible conduit is placed and over which the adhesion layer is sprayed.

[0021] The first component (i.e., the shell described above) can be left on the ceramic casting or it may be removed depending on the type or use of the shell. If the shell is thick enough to retain its dimensional characteristics, it can be removed from the casting. When the shell is used as part of a tool or die, it is often useful to include fluid passages through the shell or adjacent to the shaping surface.

[0022] For example, if the passages are used in a die, water is circulated through the die to cool the shaping surface. These water lines can be integrated to the back of the shell. Once the waterlines are placed, they are then thermally sprayed with zinc or other low melting point/high thermal conductivity metal such as steel to encapsulate and bond the water lines to the shell. The shell can now be finished using the typical spray-form tooling process.

[0023] The flexible conduits used in step b of the method of the invention are typically made from metal. However, the flexible conduits may be made from any material that can withstand the temperature present during the spraying of the metallic adhesion layer. The term "flexible" as used herein means that the conduits do not require a tool to be bent and can be bent manually. Preferably, the flexible conduits are corrugated metal tubing. Corrugated tubing is preferred over straight tubing (i.e., non-corrugated tubing) for a number of reasons. For example, corrugated tubing is easier to bend, has increased surface area, induces more turbulence in any fluids it carries, and reduces back pressure during zinc spray as compared to non-corrugated tubing. The exterior of the tube is corrugated and provide good mechanical attachment to the zinc. Prior to emplacement on the backing surface, the metal conduits can be roughened by suitable techniques such as grit blasting to increase adhesion to the metallic adhesion layer. The roughened metallic conduit is then bent to conform as close as possible to the back of the shell. Adhesive or mechanical fastening can be used to hold the tube in place. Once the tube is secured, the metal droplets are sprayed over the flexible conduit and backing surface such that the flexible conduit is at least partially encapsulated by the thus formed adhesion layer. Preferably, the metal droplets are zinc, zinc alloy, or mixture thereof. More preferably, the fine metal droplets are zinc or zinc alloy. Suitable zinc alloys include, but are not limited to, alloys containing zinc, aluminum, and copper and those containing zinc and tin. Kirksite is an example of an alloy containing zinc, aluminum, and copper. Another useful zinc alloy is Tafaloy™ Molding Wire-204M, an alloy commercially available from Tafa located in Concord, N.H. Zinc and zinc alloys provide a good backfill material because each adheres well to the steel tool (i.e., the first component) and steel conduits (i.e., the flexible conduits). The metallic adhesion layer acts as a thermal channel between the first component and the flexible conduit. The metallic adhesion layer thickness can vary depending on the amount of spray needed to fill in all voids between the first component and the flexible conduit. The shell can then be suitably backfilled.

[0024] In another embodiment of the present invention, an article having fluid passages made by the method set forth above is provided. The article of the invention comprises:

[0025] a first component having a face surface and backing surface;

[0026] a flexible conduit adjacent the backing surface; and

[0027] a metallic adhesion layer disposed over the backing surface of the first component. The metallic adhesion layer present in the article of the invention is formed by spraying metal droplets over the backing surface of the first component. Moreover, the flexible conduit is at least partially encapsulated in the metallic adhesion layer. It should be noted that the flexible conduit as used here refers to the conduit being flexible before integrated into the article of the invention. Once the conduit is encapsulated by the adhesion layer and the metallic adhesion layer has hardened, the conduit will be rigidly held in place. Finally, the specifications and particulars for the first component, flexible conduit, and the metallic adhesion layer are the same as set forth above for the method of the invention.

[0028] The article of the invention is best understood by reference to **FIG. 1**. **FIG. 1** provides perspective view of a section of an article made by the method of the present invention. The view in **FIG. 2** is such that the article has been cut across the cooling lines to expose the individual layer and a cross-section of the cooling lines. Section **2** includes component **4** and cooling lines **6, 8** partially encapsulated by metallic adhesion layer **10**. Component **4** is typically made from metal by the spray-forming process described above. Cooling lines **6, 8** are in this embodiment a corrugated tubing, typically made of stainless steel or copper. Cooling lines **6, 8** also include tube adaptors **12, 14** which provide a coupling means to a source of fluid (not shown) which flows through the cooling lines. The spacing, number, and diameter of water lines can be varied to tailor the desired cooling effect.

[0029] While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.

What is claimed:

1. A method of making an article having fluid passages, the method comprising:

(a) forming a first component having a backing surface;

(b) placing a flexible conduit capable of transporting fluid adjacent the backing surface; and

(c) spraying metal droplets atop the backing surface to form a metallic adhesion layer, wherein the metal droplets used to form the adhesion layer are sprayed in a sufficient amount that the adhesion layer at least partially encapsulates the flexible conduit whereby the conduit is fastened to the backing surface by the metallic adhesion layer.

2. The method of claim 1 wherein the flexible conduit is a corrugated metal tubing.

3. The method of claim 2 wherein the flexible conduit is copper or stainless steel.

4. The method of claim 1 wherein the conduit serves as a cooling channel.

5. The method of claim 1 wherein the first component is made by spray-forming.

6. The method of claim 1 wherein the first component is a die or a mold having a face surface.

7. The method of claim 1 wherein the first component is made from steel.

8. The method of claim 1 wherein the metal droplets are steel, zinc, zinc alloy, or mixtures thereof.

9. The method of claim 1 wherein the metal droplets are zinc or zinc alloy.

10. The method of claim 1 wherein the metal droplets are a zinc alloy comprising zinc, aluminum, and copper.

11. The method of claim 1, wherein the article is a die or mold.

12. An article having fluid passages, the article comprising:

a first component having a backing surface;

a flexible conduit adjacent the backing surface; and

a metallic adhesion layer disposed over the backing surface of the first component, wherein

the metallic adhesion layer is formed by spraying metal droplets over the backing surface of the first component; and

the corrugated conduit is at least partially encapsulated in the metallic layer.

13. The article of claim 12 wherein the flexible conduit is corrugated metal tubing.

14. The article of claim 13 wherein the flexible conduit is copper or stainless steel.

15. The article of claim 12 wherein the conduit serves as cooling channels.

16. The article of claim 12 wherein the first component is made by spray-forming.

17. The article of claim 12 wherein the first component is a die or a mold.

18. The article of claim 12 wherein the article is made from steel.

19. The article of claim 12 wherein the metal droplets are steel, zinc, zinc alloy, or mixtures thereof.

20. The article of claim 12 wherein the metal droplets are zinc or zinc alloy.

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