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(54) **METHOD FOR PRODUCING AN OBJECT FROM A HALF-FINISHED PRODUCT OF A LIGHT METAL OR A LIGHT METAL ALLOY**

(57) The invention concerns a method for producing a structured object (1) from a half-finished product (2) of a light metal or light metal alloy by forming the half-finished product (2) with an at least partly liquid medium (3), wherein the liquid medium (3) is brought into contact with the half-finished product (2) below a temperature of 0°C of the liquid medium (3) and wherein the liquid medium (3) is set under pressure in order to form the structured object (1) from the half-finished product (2).

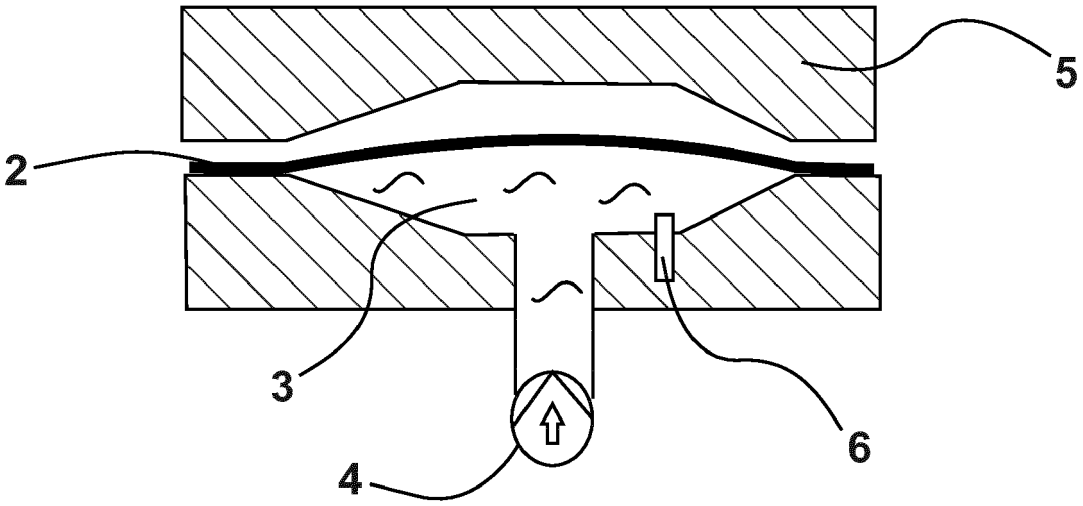

Fig. 2

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Description

[0001] The invention concerns a method for producing a structured object from a half-finished product of a light metal or light metal alloy.

[0002] The automotive and the airplane industries are both in constant search for lightweight materials and their implementation strategies in order to reduce an overall vehicle or airplane weight. Successful implementation of lightweight materials in the transportation industries would bring significant weight saving benefits to meet demands for enhancement of fuel efficiency and dynamic performance like reduction of greenhouse gases and also lowering transportation costs. Thereby, aluminum and/or magnesium alloys are increasingly chosen materials by design engineers as such lightweight metal alloys could retain rigidity and strength needed for structural applications.

[0003] However, due to lack of forming knowledge a broad application of these materials is still limited. For forming of aluminum and magnesium alloys the state of the art forming processes have been adapted. Such processes were developed mainly for forming steel grades. This kind of forming approach seems to work just in limited sectors, e.g. when forming objects at elevated temperatures by pressing tools. Moreover, light metal alloy components for the automotive and/or airplane industry are also formed by hydroforming. This process usually takes place at room temperature.

[0004] The uniform elongation, hardening behavior and tensile strength of light metal alloys is not quite satisfactory at room or elevated temperatures. However, with precise alloying the formability of aluminum and magnesium alloys at room or elevated temperatures can be extended. Room and elevated temperatures on another side impact the microstructure of the material and therefore lower their work hardening capability.

[0005] It is therefore an object of the present invention to provide a method which allows for producing an object from a half-finished product made of a light metal in an effective and cost saving manner.

[0006] According to the invention a method for producing a structured object from a half-finished product of a light metal or light metal alloy by forming the half-finished product with an at least partly liquid medium is provided, wherein the liquid medium is brought into contact with the half-finished product below a temperature of 0°C of the liquid medium and wherein the liquid medium is set under pressure in order to form the structured object from the half-finished product.

[0007] A method according to the invention allows for producing an object from al light metal alloy by route analogously to hydroforming with a very low operational effort. The object is preferably a component for use in automotive or airplane industry and may be made from a half-finished sheet or a half-finished tube. This method is free of dangerous wastes such as oil, emulsions or other substances which are harmful to the environment.

[0008] As the half-finished product is in direct contact with a cryogenic liquid medium like nitrogen during part or preferably the whole forming process, a maximal formability and work hardening can be exploited without any special tooling because of the cooling effect. Further, the method according to the invention allows optimal conditions for exploiting the whole forming potential of the half-finished product made of a light metal alloy.

[0009] The half-finished product made of a light metal alloy is formed to an object by forming with a liquid medium at usually low temperatures, in particular below 0°C, preferably below - 40°C, in particular below -100°C, like -150°C or lower. The half-finished product is placed into a negative mold which is shaped on the inner surface in a way the object should finally look like. The half-finished product is constantly contacted by the liquid medium whereby it is cooled before and, if applicable, during the hydroforming process. The half-finished product made of a light metal alloy is formable to an object which is usable as an automotive component or a component for another use. To form the object the half-finished product is pressed towards the negative mold by the liquid cryogenic medium.

[0010] The liquid medium is usually pressurized up to 1000 bar, in particular up to 3000 bar. The hydroforming process is performed with a high or ultra-high pressurized cryogenic medium. The high pressure can be established with one or more special cryogenic high pressure pumps. For this purpose, the cryogenic liquid medium can be compressed mechanically by at least one pump.

[0011] The cryogenic liquid medium can also be heated in order to increase the pressure exerted by the liquid medium. As the cryogenic medium is usually in a substantially closed system, the pressure of the cryogenic medium is raised when the cryogenic medium is heated. The high pressure is therefore established thermodynamically. Heating the cryogenic medium can produce a pressure of up to 650 bar or more. The producible pressure depends on the nature of the liquid medium and the elevated temperature. The elevated temperature is usually established by a heating element within the forming mold. Additionally, the thermodynamically produced pressure can be further increased mechanically by a high pressure pump.

[0012] In order to form the half-finished product, the cryogenic medium is usually compressed by a high pressure pump. When the cryogenic medium wants to expand again in the mold, the half-finished product is pressed and formed against an inner surface of the negative mold or a die respectively and the object is formed. Because of the constant cooling of the half-finished product made of a light metal alloy the formability and work hardening of the alloy is increased and a substantially crack free object can be produced.

[0013] Usually the liquid medium is liquid nitrogen. Liquid helium, liquid hydrogen or liquid neon is a possible alternative. Therefore, the object is particularly formed below a temperature of-150°C, in particular below-

190°C. The half-finished product is cooled during the whole forming process by the liquid medium. The cryogenic liquid medium is in direct contact with the light metal alloy during the whole forming process so that the formability of this alloy is increased. To form the object, the cryogenic liquid medium is pressurized whereby the half-finished product is pressed into a negative mold under constant contact with the cryogenic medium.

[0014] The method according to the invention can be applied to half-finished products of different shapes. In particular, the method is useful for forming half-finished products being sheets. The sheet is usually made from an aluminum alloy or a magnesium alloy. The cryogenic liquid medium is constantly contacting and therefore also cooling the sheet on one side. Further, the cryogenic medium is pressing the sheet into a negative mold when the medium is pressurized. The method can further be applied to form two sheets at the same time. For this purpose, the cryogenic medium is arranged between to mainly parallel ordered sheets, i.e. a double-sheet. When the cryogenic medium is compressed the sheets are pressed in diverging directions into two negative parts of a mold and two objects are formed simultaneously.

[0015] The method is also useful when the half-finished product is a tube. In this case, the cryogenic liquid medium is arranged inside the tube and is under permanent contact with the whole inside surface of the tube, wherein the cryogenic medium is also cooling the tube. The tube is preferably formed from an aluminum or magnesium alloy. When the cryonic liquid medium is compressed the tube is pressed into a negative mold and an object is formed.

[0016] Advantageously, the method is applied to form an automotive component or an airplane component.

[0017] Further features and advantages of the invention will become evident from the following examples. In the drawings show:

Fig. 1 a and 1 b flow curves of an aluminum alloy at different temperatures;
Fig. 2 a sectional view of an apparatus for producing an object from a half-finished sheet;
Fig. 3 a side view of an object obtained by a method according to the invention;
Fig. 4 a cut through an apparatus for producing an object from a half-finished double-sheet;
Fig. 5 a sectional view of an apparatus for producing an object from a half-finished tube.

[0018] In Fig. 1 a and 1 b flow curves of a work hardening behavior (Fig. 1 a) and formability (Fig. 1 b) of aluminum alloy AA-5182 are shown. It can be seen that the work hardening behavior as well as the formability is enhanced at cryogenic temperatures. The lower the temperature, the better are the work hardening and the formability of the aluminum alloy. A same or similar behavior can be observed for other aluminum alloys and also magnesium alloys. This leads to the conclusion that in order to produce objects for the automotive or airplane industry a forming process should be performed at low temperatures.

[0019] Fig. 2 shows a sectional view through an apparatus for producing an object 1 from a half-finished product 2. Here, the half-finished product 2 is a sheet. The half-finished product 2 is placed inside a negative mold 5. For forming the half-finished product 2 and hence producing an object 1, the half-finished product 2 is pressed in the mold 5 by a cryogenic liquid medium 3 like liquid nitrogen. According to the inventive method, the half-finished product 2 is constantly contacting the cryogenic liquid medium 3 during the whole forming process. The cryogenic medium 3 is preferably a liquid medium at very low temperature of -150°C or lower. Therefore, the half-finished product 2 is cooled during the forming process which increases the formability of the light metal alloy half-finished product 2. The hydroforming process is performed under a high pressure, for which the cryogenic liquid medium 3 is pressurized. The high pressure is preferably established thermodynamically in combination with a high pressure pump 4. The cryogenic medium 3 is heated with a heating element 6, whereby a pressure of up to 650 bar can be applied in the forming process. The pressure is further increased by the high pressure pump 4. As the cryonic liquid medium 3 is pressurized the half-finished product 2 is pressed into the mold 5 by the cryogenic liquid medium 3. The object 1 is thus produced. The corresponding object 1 is depicted in Fig. 3 showing the form of the part.

[0020] Fig. 4 depicts a sectional view through another apparatus for producing an object 1 from a half-finished product 2 which is constructed to produce simultaneously two objects 1 from two half-finished sheets. The cryogenic liquid medium 3 is injected between the sheets and the sheets are pressed towards an inner surface of the molds 5 when the liquid medium 3 is pressurized. Again, there is provided a high pressure pump 4 and a heating element 6 to pressurize the cryogenic medium 3.

[0021] Fig. 5 shows a sectional view through another apparatus for producing an object 1 from a half-finished product 2. Here, the half-finished product 2 is a tube and the cryogenic liquid medium 3 is injected in the middle of the tube. The cryogenic liquid medium 3 is pressurized thermodynamically by a heating element 6 and further with a high pressure pump 4. Consequently the half-finished tube is pressed outwardly in a negative mold 5, whereby the object 1 is formed.

Claims

1. A method for producing a structured object (1) from a half-finished product (2) of a light metal or light metal alloy by forming the half-finished product (2) with an at least partly liquid medium (3), wherein the liquid medium (3) is brought into contact with the half-finished product (2) below a temperature of 0°C

of the liquid medium (3) and wherein the liquid medium (3) is set under pressure in order to form the structured object (1) from the half-finished product (2).

2. The method according to claim 1, wherein the liquid medium (3) is pressurized up to 1000 bar, in particular up to 3000 bar.

3. The method according to claim 1 or 2, wherein the liquid medium (3) is heated in order to increase the pressure exerted by the liquid medium (3).

4. The method according to one of claims 1 to 3, wherein the liquid medium (3) is compressed by a high pressure pump (4).

5. The method according to one of claims 1 to 4, wherein the liquid medium (3) is nitrogen.

6. The method according to one of claims 1 to 5, wherein the half-finished product (2) is formed against an inner surface of a tool.

7. The method according to one of claims 1 to 6, wherein the half-finished product (2) is a sheet.

8. The method according to one of claims 1 to 6, wherein the half-finished product (2) is a tube.

9. The method according to one of claims 1 to 8, wherein the object (1) is an automotive component or an airplane component.

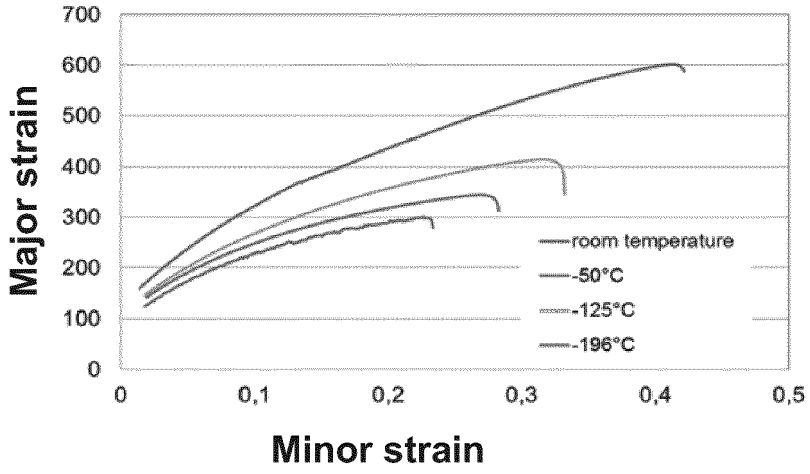
Major strain
700
600
500
400
300
200
100
0
0
0,1
0,2
0,3
0,4
0,5
Minor strain
room temperature
-50°C
-125°C
-196°C

Fig. 1a

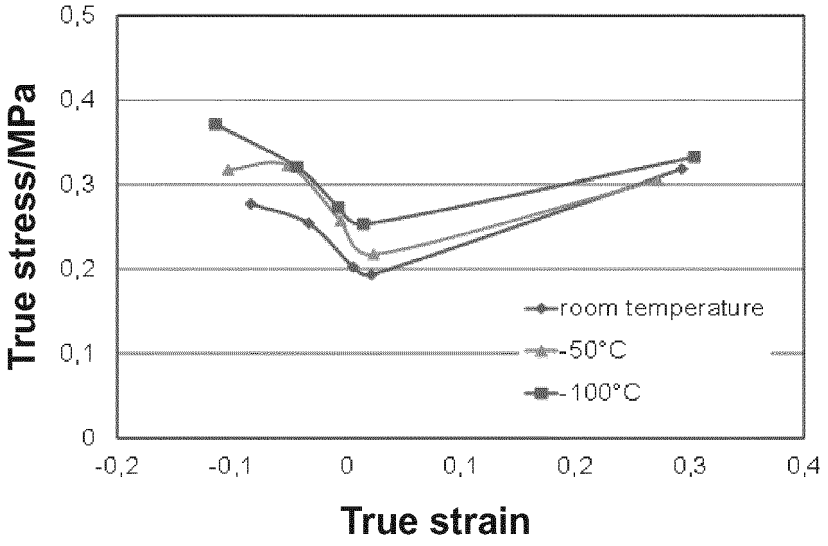
True stress/MPa
0,5
0,4
0,3
0,2
0,1
0
-0,2
-0,1
0
0,1
0,2
0,3
0,4
True strain
room temperature
-50°C
-100°C

Fig. 1b

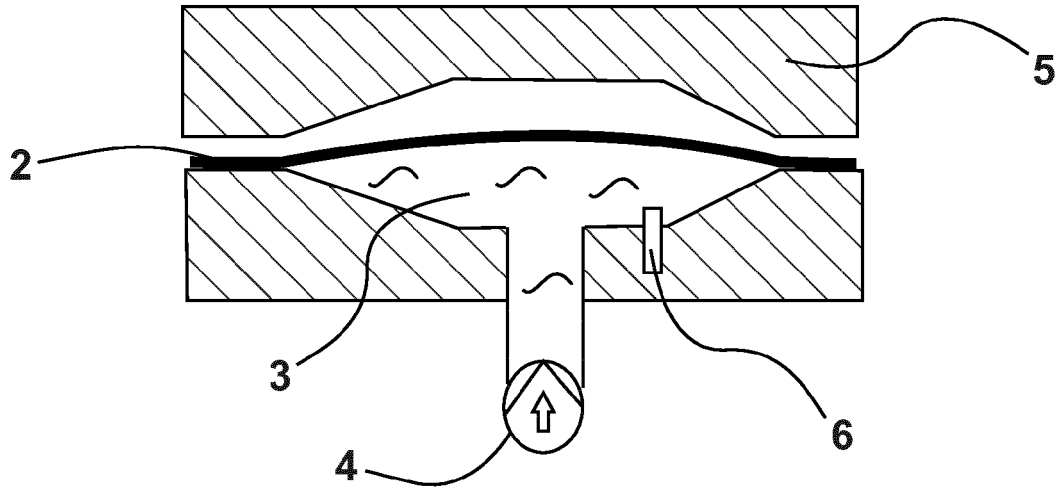

Fig. 2

Fig. 3

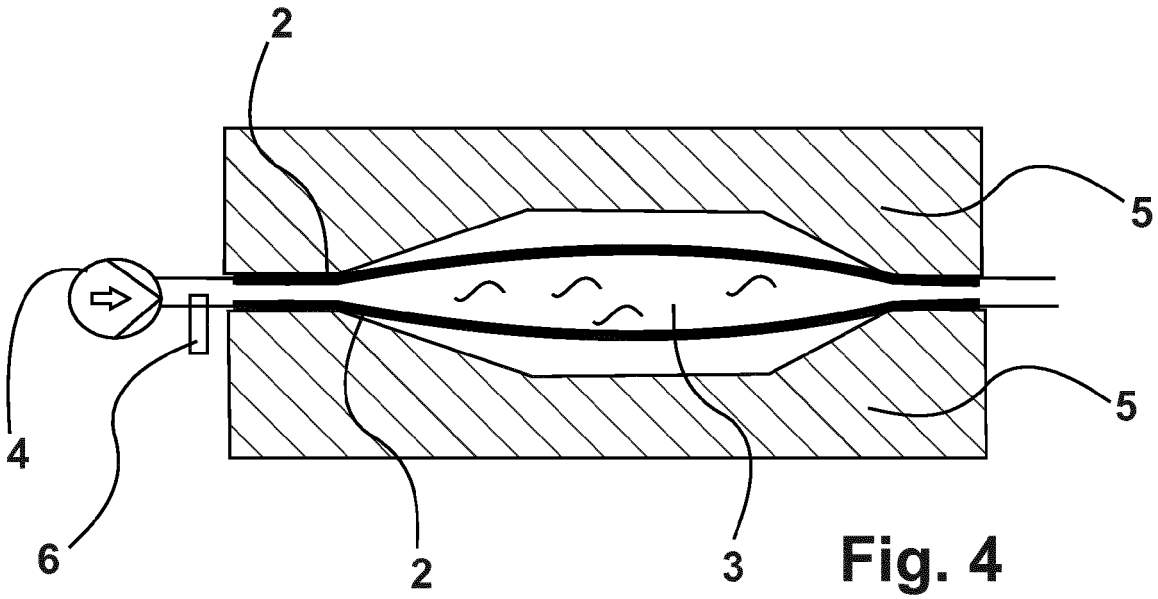

Fig. 4

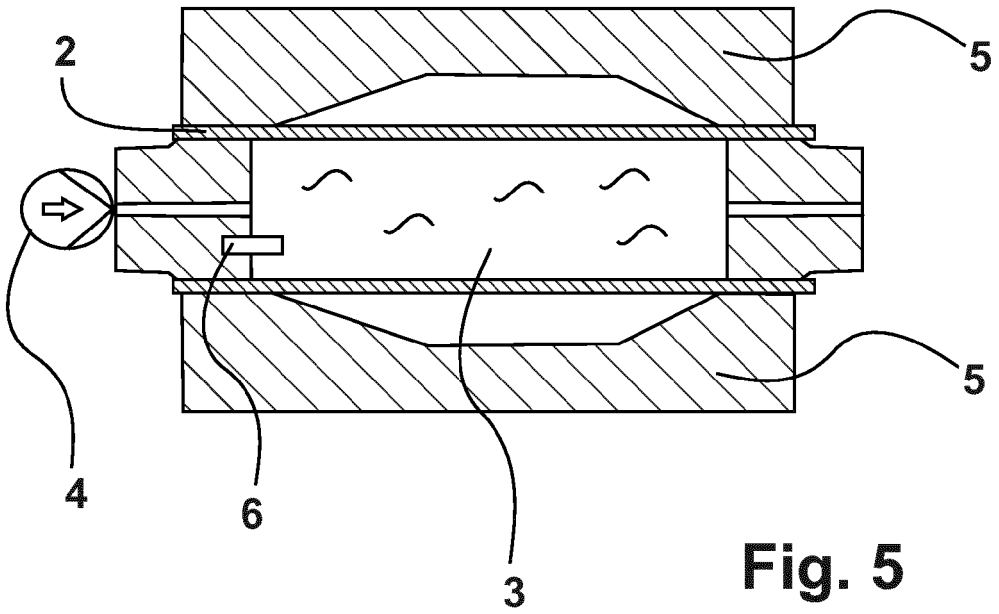

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 7695

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP H08 112626 A (NISSAN MOTOR) 7 May 1996 (1996-05-07) * paragraphs [0001], [0035], [0036]; figure 3 *	1-9	INV. B21D26/053 B21D26/027 B21D26/041
X	US 3 266 946 A (CHARLES MERLIN ANDRE EMILE) 16 August 1966 (1966-08-16) * column 1, lines 47-51; figures * * column 3, lines 3-15 * * column 4, lines 3-7 *	1-9	ADD. B21D53/88 B21D53/92
X	US 4 159 217 A (SELINES RONALD J [US] ET AL) 26 June 1979 (1979-06-26) * column 1, lines 34-41 * * column 3, line 39 *	1-9	
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X	DE 10 2012 015320 A1 (FRAUNHOFER GES ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E V [DE]) 15 May 2014 (2014-05-15) * paragraphs [0034], [0095], [0122]; claim 9 *	1-9	TECHNICAL FIELDS SEARCHED (IPC) B21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	9 February 2017	Knecht, Frank

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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09-02-2017

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