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(54) **METHOD AND SYSTEM FOR FORMING ALUMINUM ALLOY BLANK**

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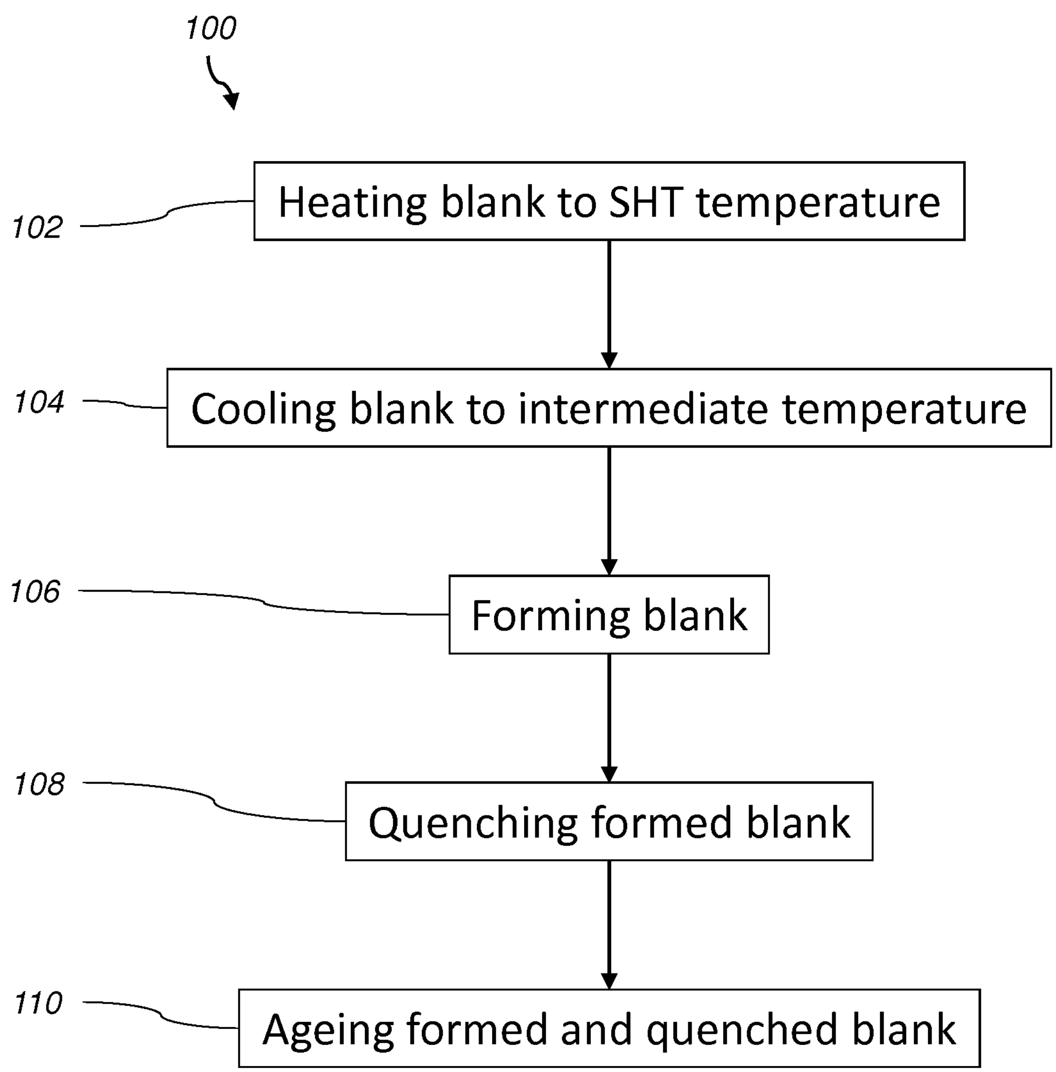
(57) **ABSTRACT**

The present invention relates to a method of forming a 6xxx or 7xxx series Al alloy blank is provided. The method comprises the steps of heating the blank to a solutionization (SHT) temperature, T_{SHT}, for the alloy of the blank at a heating station and keeping the blank at said SHT temperature until SHT is complete, cooling the blank at a cooling station to an intermediate temperature, T_{ITM}, at which the kinetic movement for the alloy in the blank stops and at a cooling rate that is high enough such that re-crystallization in the alloy of the blank does not occur, forming the blank in a forming tool, quenching the formed blank to room temperature, T_E, and artificially ageing the formed and quenched blank in an ageing station. The present invention further relates to a 6xxx or 7xxx series Al alloy blank forming system (**1**, **3**).



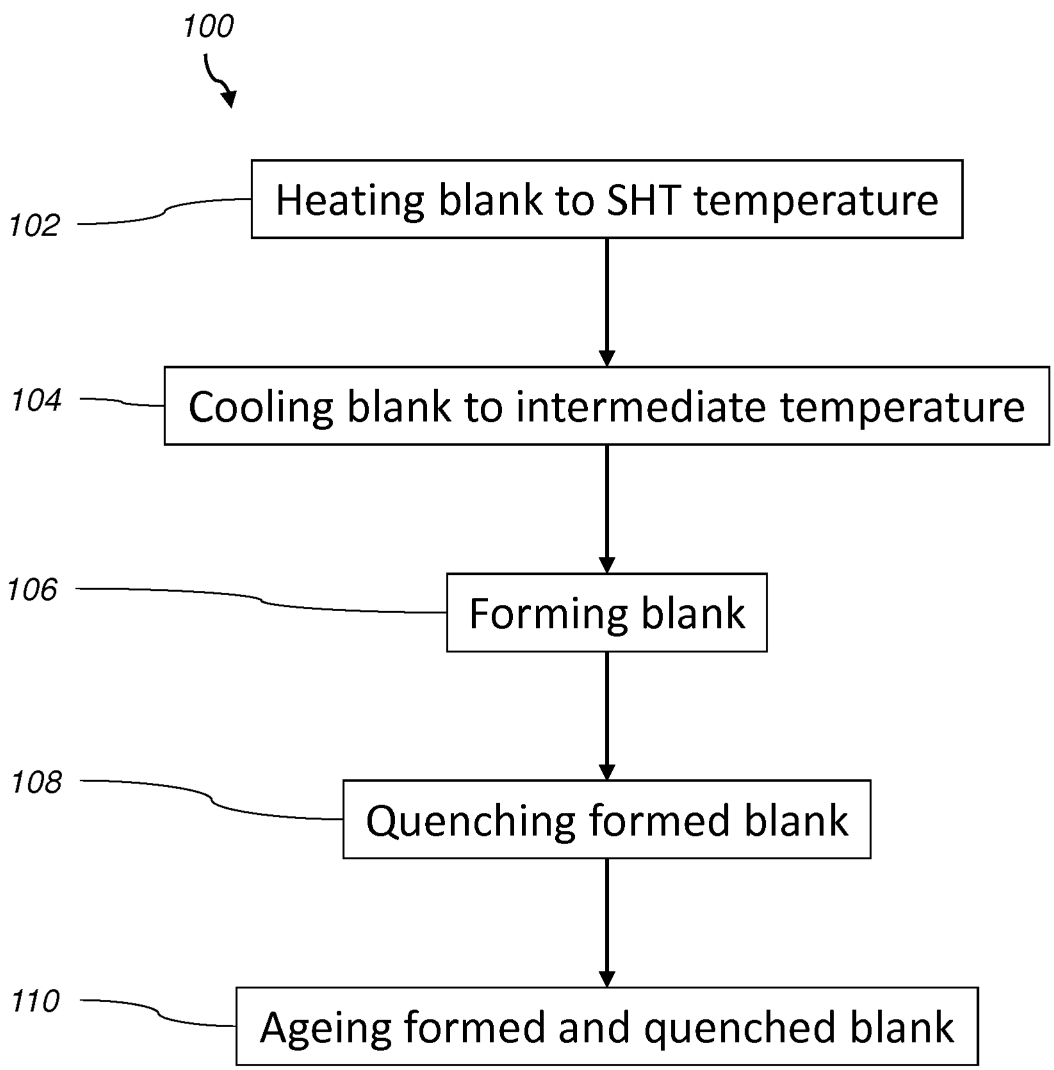

100
102
Heating blank to SHT temperature
104
Cooling blank to intermediate temperature
106
Forming blank
108
Quenching formed blank
110
Ageing formed and quenched blank

Fig. 1

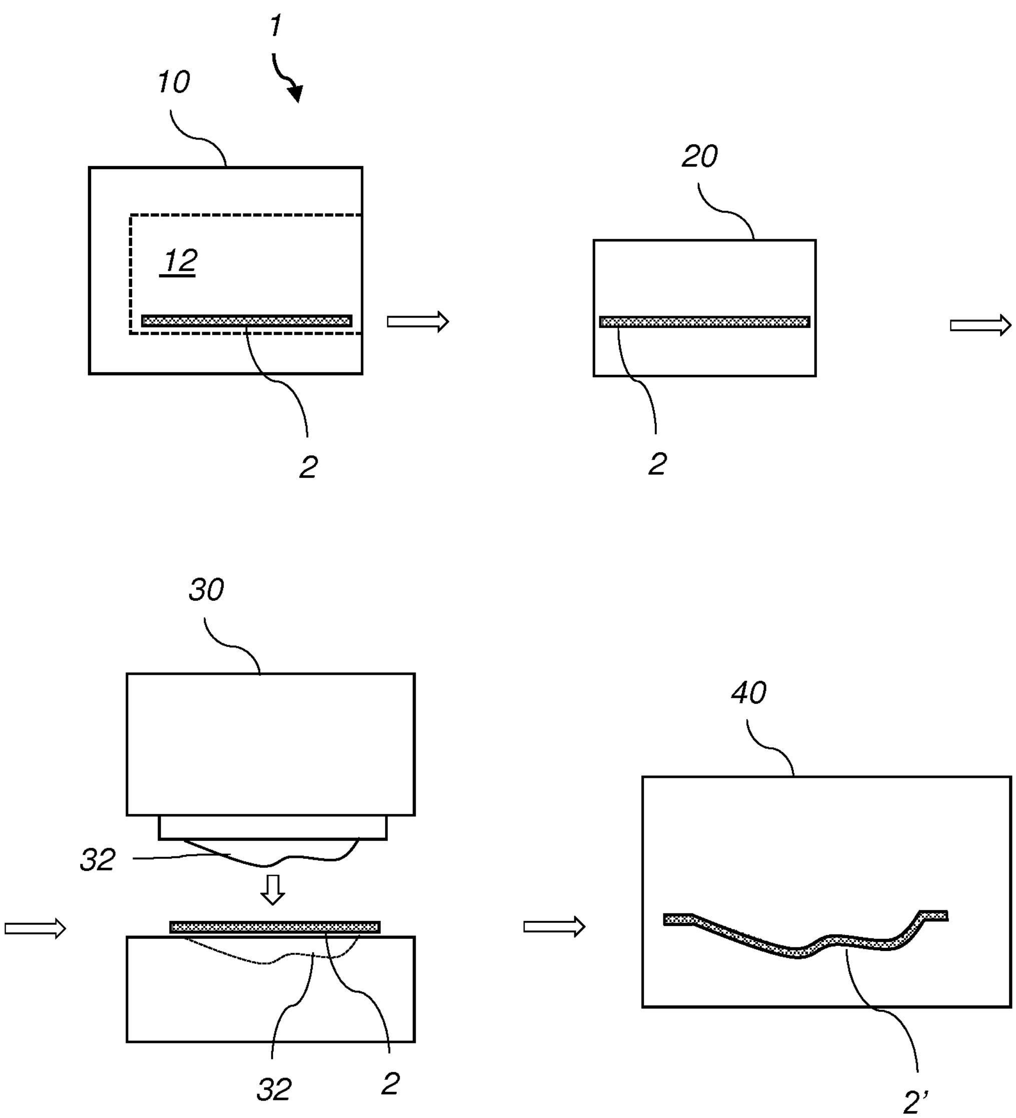


Fig. 2

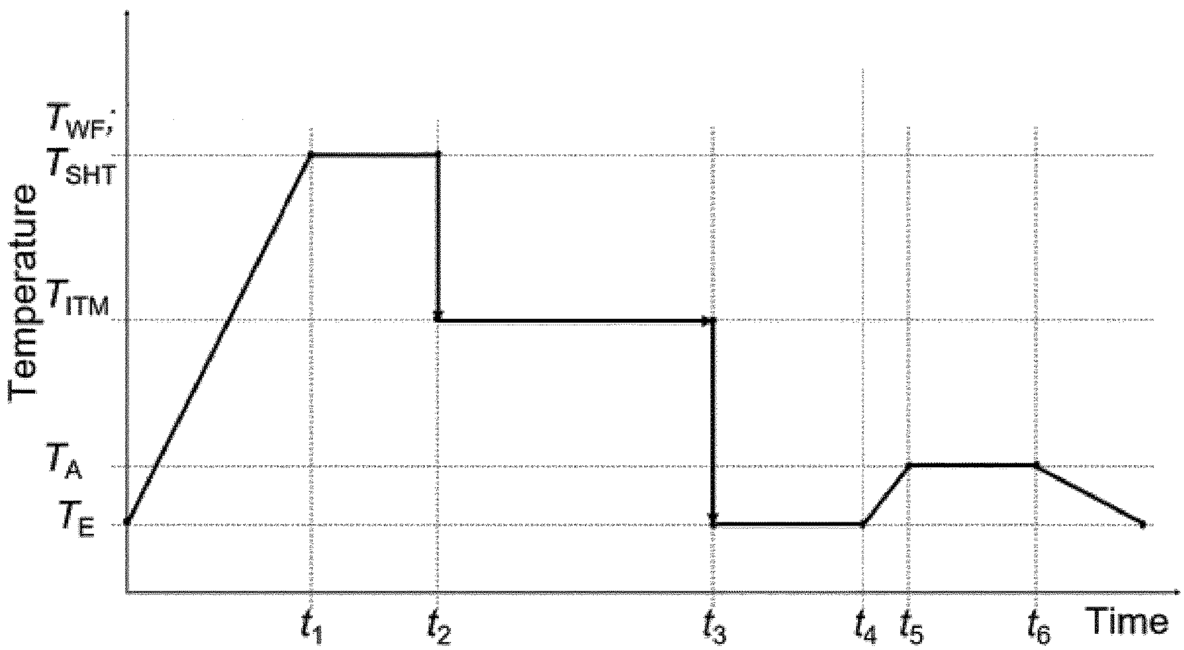


Fig. 3

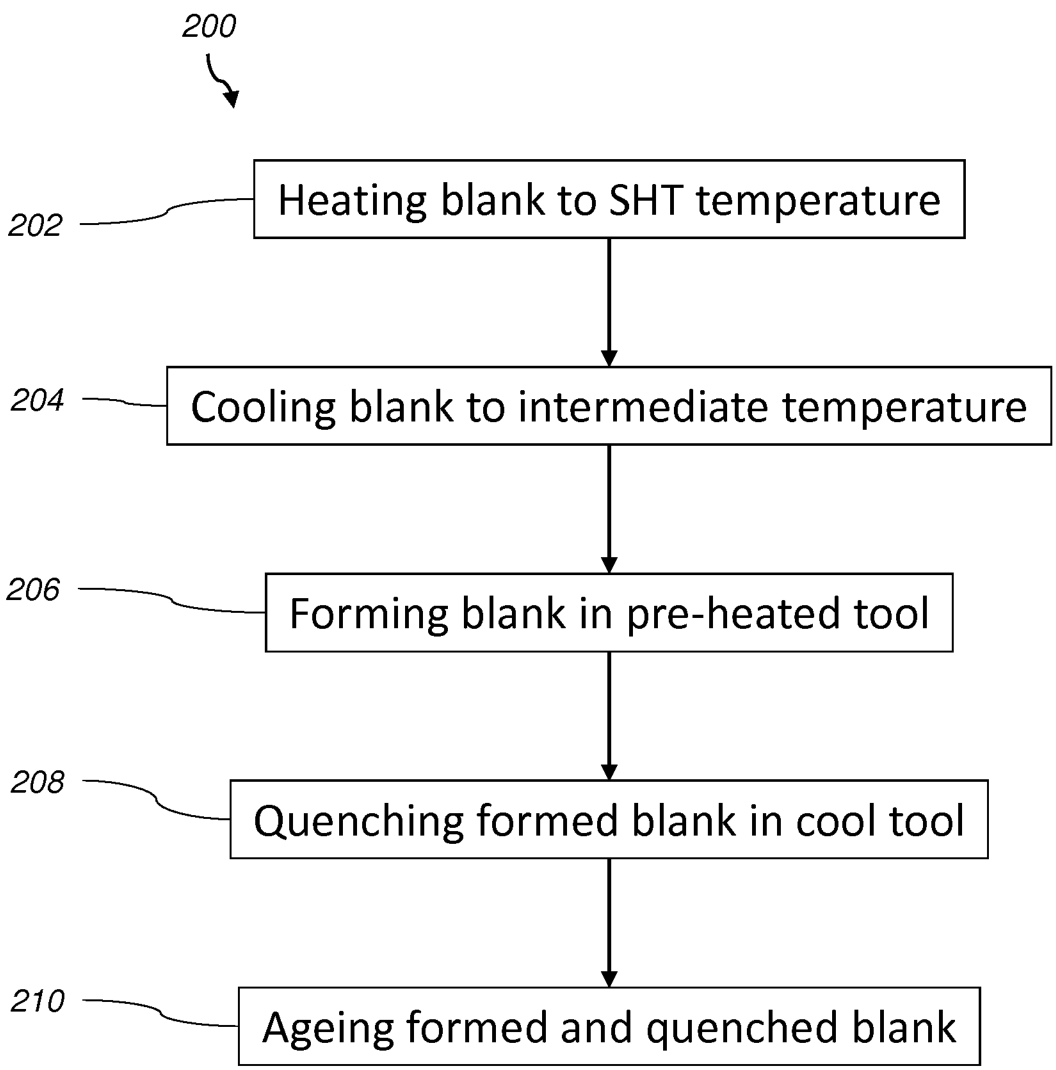

200
202
Heating blank to SHT temperature
204
Cooling blank to intermediate temperature
206
Forming blank in pre-heated tool
208
Quenching formed blank in cool tool
210
Ageing formed and quenched blank

Fig. 4

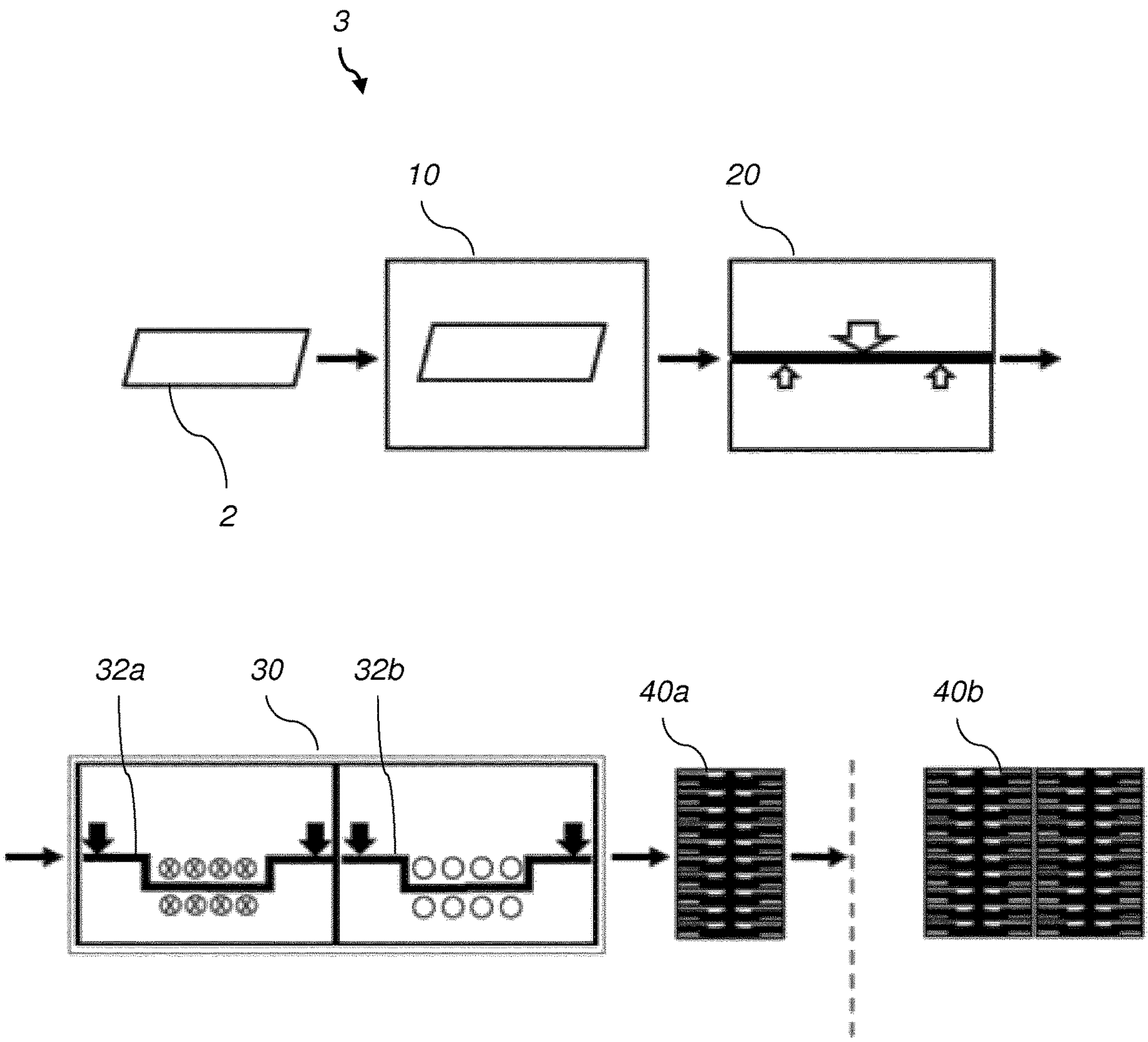


Fig. 5

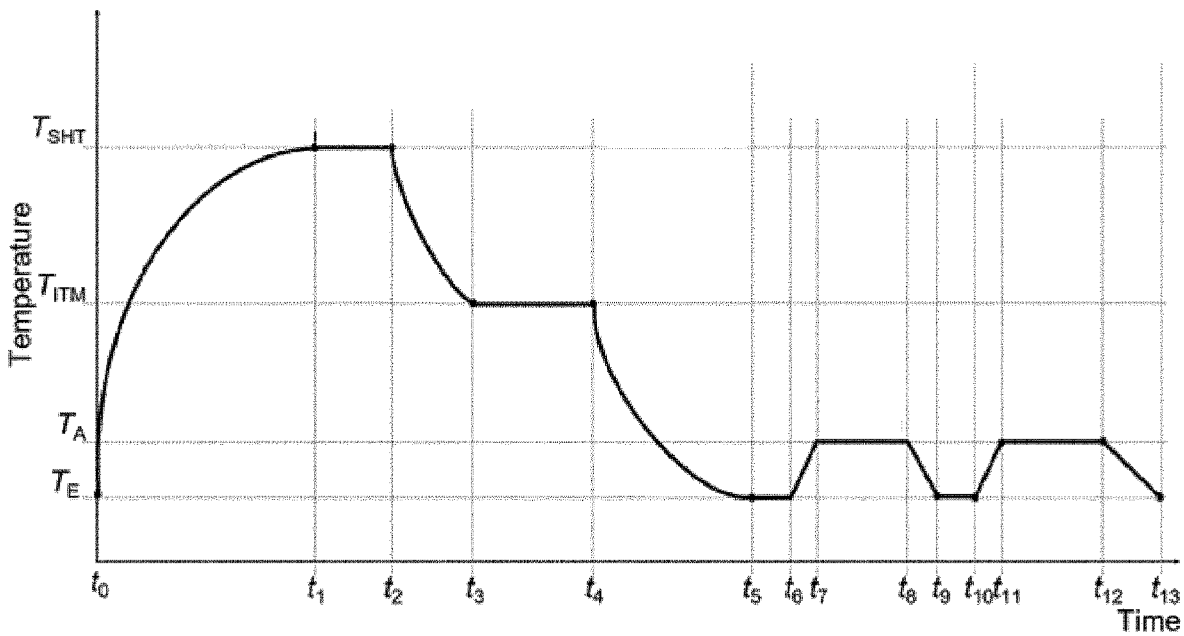

T_{SHT}
T_{ITM}
Temperature
T_A
T_E
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
t_8
t_9
t_{10}
t_{11}
t_{12}
t_{13}
Time

Fig. 6

METHOD AND SYSTEM FOR FORMING ALUMINUM ALLOY BLANK

TECHNICAL FIELD

[0001] The present disclosure relates to a heat treatment method of blank sheets of aluminum alloys, and especially to a method suitable for blank sheets of any aluminum alloy grade, composition or temper.

BACKGROUND

[0002] In especially the automotive industry, the hot forming of blank sheets is important, in particular hot forming of blank sheets of high strength aluminum alloys. There are numerous methods known for forming aluminum alloy blanks. E.g. the hot forming die quenching methods as presented in WO2010/032002 and WO2015/136299.

[0003] However, such known methods have several drawbacks. For instance, these methods are not suitable for all aluminum alloy grades. The method in WO2010/032002 may be suitable for AA6082 material, but not for any AA7xxx material. Further, the aluminum alloy grade material compositions and tempers may vary from different material suppliers. The resulting formed components using the known methods are very sensitive to different compositions and tempers.

[0004] Further, the known processes have problems in being suitable for mass production due to lack of stability, repeatability and accuracy of the formed components.

[0005] Consequently, there is a need for production method for forming aluminum alloy blank sheets which alleviate the mentioned drawbacks of known technology.

SUMMARY

[0006] It is an object of the present invention to provide an improved solution that alleviates the mentioned drawbacks with present devices. Furthermore, it is an object to provide a method resulting in improved accuracy of the formed parts and which method is suitable for any aluminum alloy grade, composition and temper.

[0007] The invention is defined by the appended independent claims, with embodiments being set forth in the appended dependent claims, in the following description and in the drawings.

[0008] According to a first aspect of the present invention, a method of forming a 6xxx or 7xxx series Al alloy blank into a component is provided. The method comprises the steps of heating the blank to a solutionization (SHT) temperature, T_{SHT}, for the alloy of the blank at a heating station and keeping the blank at said SHT temperature until SHT is complete, cooling the blank at a cooling station to an intermediate temperature, T_{ITM}, at which the kinetic movement for the alloy in the blank stops and at a cooling rate that is high enough such that re-crystallization in the alloy of the blank does not occur, forming the blank in a forming tool, quenching the formed blank to room temperature, T_E, and artificially ageing the formed and quenched blank in an ageing station.

[0009] By using a method according to the present invention, a method is provided that, with high accuracy of the formed components and low amount of springbacks, is suitable for any 6xxx or 7xxx series aluminum alloy grade sheet blank.

[0010] The time in which the blank is kept at or above the solution heat treatment (SHT) temperature may be chosen to be sufficient to ensure maximum concentration of hardening elements, such as copper, zinc, magnesium, manganese, silicon etc. in the solid solution. The concentration and rate of dissolution of these elements in the solid solution may increase with increasing temperature.

[0011] By cooling the blank at a specific cooling rate the SHT composition of the solid solution may be preserved at the intermediate temperature. If the blank were to be cooled in a too slow rate, the alloying elements may diffuse through the solid solution and concentrate at the grain boundaries, in large voids, undissolved particles or other undesired locations. To achieve improved strength properties of the formed part, it may be desirable to avoid such recrystallization and decrease the diffusion process and maintain the alloying elements in the solid solution by providing a rapid cooling. The cooling rate to achieve this may be selected depending on the aluminum alloy grade and composition of the blank. Further, a quenching rate may be selected depending on the aluminum alloy grade and composition of the blank.

[0012] The intermediate temperature may be a temperature in an intermediate temperature range being above room temperature and below the SHT temperature. In the intermediate temperature range, the time required for a given amount of precipitation may increase due to low solute diffusion coefficients. Though the thermodynamic potential for precipitation for most aluminum alloy grades are mostly high at the intermediate temperature because of the high degree of solute supersaturation, the rate of precipitate formation is low due to the inability of atoms to diffuse, increased nucleation or precipitation and growth at the temperature range.

[0013] As an example, an intermediate temperature for a 7xxx series Al alloy blank may be chosen between 400-420° C. Further, for a AA6082 Al alloy blank, the intermediate temperature may be chosen as 300-350° C. At such temperatures, the kinetic movement in the alloy material of the blank may have stopped.

[0014] The cooling to the intermediate temperature may be performed at a cooling station being separate from the forming tool. The cooling may thereby be provided fast and with homogeneous temperature in the blank.

[0015] As an example, for a 6xxx series Al alloy (such as AA6082), a cooling rate of at least 30 K/s may be chosen. Further, for a 7xxx series Al alloy, a cooling rate of at least 30 K/s, at least 50 K/s, or preferably about 100 K/s, may be chosen.

[0016] In one embodiment, the intermediate temperature may be selected depending on the Al alloy of the blank, and being above 100° C. The intermediate temperature should be selected as a temperature wherein the kinetic movement of the alloy material of the blank stops. Depending on which 6xxx or 7xxx series Al alloy is used in the blank, the optimal intermediate temperature may differ. However, the intermediate temperature may be above 100° C. Further, the intermediate temperature may be selected being the highest possible temperature at which the kinetic movement in the present alloy material stops.

[0017] In one embodiment, the forming tool may be preheated to the intermediate temperature. The blank may thereby be formed at the intermediate temperature. The temperature of the blank may thereby be controlled during the forming, which may improve the accuracy in the properties of the final formed component.

[0018] In one embodiment, the blank may be kept at the intermediate temperature during the forming step in the forming tool. The temperature of the tool may be controlled in order to keep the temperature of both the tool and the blank stable at the intermediate temperature during the forming. After the forming, the temperature of the forming tool may be controlled in order to quench the formed blank to room temperature. A temperature control function may be provided for the forming tool in order to control the temperature of the forming tool to the intermediate temperature throughout the forming step.

[0019] In one embodiment, the forming and the quenching may be performed in separate forming tools. A first forming tool may form the blank at the intermediate temperature, and a second forming tool may quench the blank to room temperature. In a further embodiment, the first forming tool may be preheated to the intermediate temperature, thereby keeping the blank at the intermediate temperature during the forming. The blank may then be transferred to the second forming tool, quenching the blank to room temperature. The second forming tool may be a cold forming tool. Alternatively, the first forming tool may not be preheated, thereby cooling the blank during the forming. The blank may then in the second forming tool be quenched in a controlled manner to room temperature in the second forming tool.

[0020] According to a second aspect of the present invention, a 6xxx or 7xxx series Al alloy blank forming system is provided. The system comprises a heating station configured to heat a blank to its SHT temperature, T_{SHT}, a cooling station configured to cool the blank to an intermediate temperature T_{ITM}, at which the kinetic movement for the alloy in the blank has stopped and at a cooling rate that is high enough such that re-crystallization in the alloy of the blank does not occur, a forming tool configured to form and quench the blank, and an ageing station configured to provide an artificial ageing process to the formed and quenched blank.

[0021] By a heating station being configured to heat a blank to its SHT temperature it may be meant a heating station comprising means capable of heating a blank inserted into the heating station to its SHT temperature. By a cooling station configured to cool the blank to an intermediate temperature at which kinetic movement for the alloy in the blank has stopped and at a cooling rate that is high enough such that re-crystallization in the alloy of the blank does not occur it may be meant a cooling station comprising means capable of cooling a blank in the specified way. By a forming tool configured to form and quench a blank it may be meant a forming tool comprising means capable of forming and quenching the blank. By an ageing station configured to provide an artificial ageing process to the formed and quenched blank it may be meant an ageing station comprising means capable of such artificial ageing process.

[0022] Further embodiments of the system according to the present invention may be provided similarly as discussed above for the method. The heating station, the cooling station, the forming tool and/or the ageing station may further comprise means capable of providing additional functions as discussed above for the method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The invention will in the following be described in more detail with reference to the enclosed drawings, wherein:

[0024] FIG. **1** shows a flow chart of a method according to an embodiment of the invention;

[0025] FIG. **2** shows a block scheme of a system according to an embodiment of the invention;

[0026] FIG. **3** shows a diagram view of a process of the method according to an embodiment of the invention;

[0027] FIG. **4** shows a flow chart of a method according to an embodiment of the invention;

[0028] FIG. **5** shows a block scheme of a system according to an embodiment of the invention; and

[0029] FIG. **6** shows a diagram view of a process of the method according to an embodiment of the invention.

DESCRIPTION OF EMBODIMENTS

[0030] The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements.

[0031] As illustrated in FIG. **1**, a method **100** according to an embodiment of the present invention comprises a first step of heating **102** a 6xxx or 7xxx series Al alloy blank **2** to the solutionization (SHT) temperature for the specific alloy of the blank **2**. As further seen in FIG. **2**, a blank forming system **1** is provided, wherein the heating **102** is performed in a heating station **10**. In the heating station **10**, when the blank **2** has reached its SHT temperature or above, the temperature of the blank **2** is kept at the SHT temperature or above until the solutionization of the alloy of the blank **2** is complete.

[0032] In a next step, the blank **2** is cooled **104** to an intermediate temperature. In the blank forming system **1**, the cooling **104** is performed at a cooling station **20**. The intermediate temperature is selected for the alloy of the blank **2** at which temperature the kinetic movement for the alloy stops. The cooling **104** is performed at a cooling rate high enough such that re-crystallization in the alloy of the blank **2** does not occur.

[0033] In a next step, the blank **2** is formed **106** in a forming tool **32** at a press station **30** in the blank forming system **1**. The press station **30** may be a press suitable for aluminum alloy blank sheet forming, such as a hydraulic press, a servo press (servo hydraulic or servo mechanical).

[0034] After forming **106** of the blank **2**, the formed blank **2'**, or formed component **2'**, is quenched **108** in the forming tool **32** to room temperature.

[0035] Finally, the formed blank **2'** is artificially aged **110** at an ageing station **40**. The ageing process is provided to control and limit the recrystallization in the alloy material of the blank **2**.

[0036] FIG. **3** illustrates the blank forming method **100** according to an embodiment of the present invention. The blank **2** is heated from room temperature T_E to the SHT temperature T_{SHT}, and kept at the T_{SHT} for a necessary time

t_1–t_2 as discussed above. At t_2 the blank **2** is rapidly cooled to the intermediate temperature T_{ITM} at the necessary cooling rate as discussed above. The blank **2** is then formed during t_2–t_3 in the forming tool **32**. At t_3 the formed blank **2'** is quenched to room temperature T_E.

[0037] At the ageing station **40**, the formed component **2'** is processed for artificial ageing by being heated to an ageing temperature T_A. The component **2'** is kept at the ageing temperature T_A during a period t_5–t_6 until the ageing process is complete. The time t_3–t_4 provides a transfer of the formed blank to the ageing station **40**.

[0038] The blank **2** is transferred between the different stations **10**, **20**, **30**, **40**. The transfer may be performed such that minimal heat loss in the blank **2** is achieved.

[0039] FIGS. **4** and **5** illustrates a method **200** and system **3** according to an embodiment of the invention. The steps of heating **202** and cooling **204** correspond to the steps **102** and **104** as discussed above. Next, the blank **2** is formed **206** in a preheated first forming tool **32***a* at a press station **30** in the blank forming system **3**. The first forming tool **32***a* is preheated to the intermediate temperature. The blank **2** is thereby not further cooled when arranged in the first forming tool **32***a*. The intermediate temperature may be kept in the first forming tool **32***a* and the blank **2** throughout the forming process **106**.

[0040] Next, the formed blank is moved to a separate cold second forming tool **32***b*. In the cold second forming tool **32***b*, the blank is quenched to room temperature. The cold second forming tool **32***b* may further form and quench the blank to its final shaped component.

[0041] FIG. **5** further illustrates an optional arrangement of ageing which can be used for either of the above presented embodiments. In such ageing embodiment, a first pre-ageing step is performed at a pre-ageing station **40***a*, in which the formed component **2'** is heated to the ageing temperature T_A, kept at T_A until the pre-ageing is complete and then cooled to room temperature T_E. After transfer to a second ageing station **40***b*, the component **2'** is again heated to T_A, kept at T_A for a time period and thereafter cooled to room temperature T_E, to provide a paint baking of the component **2'**. Alternatively, the component can be heated to a different temperature in the paint baking process than the temperature T_A in the pre-ageing process. A two-step ageing process is thereby provided comprising pre-ageing and paint baking.

[0042] Preferably, the pre-ageing process is integrated in the forming/stamping line, and performed in direct connection to the forming of the component **2'**. The paint baking process may be performed at a later stage, whichever may be suitable for the production line.

[0043] The use of the pre-ageing process prevents natural ageing after stamping in the second forming tool. Otherwise, natural ageing may occur after about 30 minutes for 7xxx series Al alloy materials or about one hour for 6xxx series Al alloy materials. The paint baking process cannot take effect on the formed component to achieve peak hardness. The pre-ageing process further enables post processing activities such as transport to another location, storage for a required period before assembly or joining operations. Then, the paint baking operation may be performed at the most suitable time to provide optimal peak hardness in a short cycle time and at a low cost. This may e.g. be after joining the formed component **2'** to a desired assembly.

[0044] FIG. **6** illustrates the process blank forming method **200** according to an embodiment of the present invention. The blank **2** is heated from room temperature T_E to the SHT temperature T_{SHT}, and kept at the T_{SHT} for a necessary time t_1–t_2 as discussed above. Between t_2 and t_3, the blank **2** is cooled to the intermediate temperature T_{ITM} at the necessary cooling rate as discussed above. The blank **2** is then formed during t_3–t_4 in the preheated first forming tool **32***a*. Between t_4 and t_5 the formed blank **2'** is quenched to room temperature T_E in the second forming tool **32***b*.

[0045] FIG. **6** further illustrate the process of the embodiment comprising a pre-ageing and a paint baking step as discussed above. At the pre-ageing station **40***a*, the formed blank **2'** is processed for artificial ageing by being heated to the ageing temperature T_A and kept at the ageing temperature T_A during a period t_7–t_8. After being cooled to room temperature, the blank **2'** is in the second ageing station **40***b* again heated to the ageing temperature T_A and kept at T_A between t_{11}–t_{12} until the ageing process is complete. The blank **2'** formed to a final shaped component is then again cooled to room temperature T_E.

[0046] In the drawings and specification, there have been disclosed preferred embodiments and examples of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation, the scope of the invention being set forth in the following claims.

1. A method of forming a 6xxx or 7xxx series Al alloy blank, wherein the method comprises the steps of:

heating the blank to a solutionization (SHT) temperature (T_{SHT}) for the alloy of the blank at a heating station and keeping the blank at said SHT temperature until SHT is complete,

cooling the blank at a cooling station to an intermediate temperature (T_{ITM}) and at a cooling rate that is high enough such that re-crystallization in the alloy of the blank does not occur wherein for a 6xxx series Al alloy blank the intermediate temperature is between 300-350° C. and the cooling rate is at least 30 K/s, and for a 7xxx series Al alloy blank the intermediate temperature is between 400-420° C. and the cooling rate is at least 50 K/s,

forming the blank in a forming tool,

quenching (**108**) the formed blank (**2'**) to room temperature (TE),

pre-ageing the formed and quenched blank in a pre-ageing station within one hour of the quenching of the formed blank for a 6xxx series Al alloy blank and within 30 minutes of the quenching of the formed blank for a 7xxx series alloy blank, in which pre-ageing the formed and quenched blank is heated to an ageing temperature (T_A), kept at the ageing temperature during a time period, and cooled to room temperature.

2. (canceled)

3. The method according to claim **1**, wherein the forming tool is preheated to the intermediate temperature (T_{ITM}).

4. The method according to claim **1**, wherein the blank is kept at the intermediate temperature (T_{ITM}) during the forming in the forming tool.

5. The method according to claim **1**, wherein the forming is performed in a first forming tool and the quenching is performed in a second forming tool.

6. A 6xxx or 7xxx series Al alloy blank forming system comprising, a heating station configured to heat a blank to its SHT temperature (T_{SHT}),

a cooling station configured to cool the blank to an intermediate temperature (T_{ITM}) and at a cooling rate that is high enough such that re-crystallization in the alloy of the blank does not occur, wherein for a 6xxx series Al alloy blank the intermediate temperature is between 300-350° C. and the cooling rate is at least 30 K/s, and for a 7xxx series Al alloy blank the intermediate temperature is between 400-420° C. and the cooling rate is at least 50 K/s

at least one forming tool configured to form and quench the blank, and

a pre-ageing station configured to provide an artificial pre-ageing process to the formed and quenched blank, wherein the pre-ageing station is arranged relative to the forming tool such that the pre-ageing can take place within one hour of the quenching of the formed blank for a 6xxx series Al alloy blank and within 30 minutes of the quenching of the formed blank for a 7xxx series alloy blank, and wherein the pre-ageing station is configured to heat the formed and quenched blank to an ageing temperature (T_A), keep it at the ageing temperature during a time period, and cool it to room temperature.

7. (canceled)

8. The system according to claim **6**, wherein the forming tool is configured to be preheated to the intermediate temperature prior to forming the blank.

9. The system according to claim **5**, wherein the forming tool is configured to keep the blank at the intermediate temperature (T_{ITM}) during the forming in the forming tool.

10. The system according to claim **5**, wherein the system comprises a first forming tool configured to form the blank, and a second forming tool configured to quench the blank.

* * * * *