METHOD AND HOT FORMING SYSTEM FOR PRODUCING A HARDENED, HOT FORMED WORKPIECE

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ABSTRACT
A method for producing a hardened, hot formed workpiece (2) of sheet steel, comprising at least partially heating a workpiece blank to a forming temperature in at least one furnace, introducing the heated workpiece blank into at least one drawing press, and forming the heated workpiece blank into a workpiece in the at least one drawing press. To be able to produce particularly high quantities of hardened, hot formed workpieces in a more cost-efficient manner, provision is made for introducing the formed workpiece into at least one hardening device, fixing the formed workpiece in a receiver of the hardening device which is adapted to the geometry of the formed workpiece, and at least partially hardening the formed workpiece in the receiver by means of direct heat exchange with a cooling medium.
METHOD AND HOT FORMING SYSTEM FOR PRODUCING A HARDENED, HOT FORMED WORKPIECE

[0001] The invention relates to a method for producing a hardened, hot formed workpiece of sheet steel, wherein a workpiece blank is at least partially heated in at least one furnace to a forming temperature, wherein the heated workpiece blank is introduced into at least one drawing press and wherein the heated workpiece blank is formed into a workpiece in the at least one drawing press. The invention further relates to a hot forming system for producing a hardened, formed workpiece of steel, comprising a furnace for at least partially heating a workpiece blank to a forming temperature, comprising a drawing press for forming the workpiece blank and comprising a transfer device for transferring the heated workpiece blank from the furnace to the drawing press.

[0002] Such systems serve the purpose of producing high-strength body parts from sheet steel, for example. Hot forming systems typically comprise a furnace system for heating the workpiece blanks as well as a press system for forming and hardening the workpiece blanks. After heating of the workpiece blanks to a predetermined forming temperature, they are removed from the furnace system and are placed into a drawing press. The tools of the drawing press are cooled via a cooling medium, so that the workpiece is quickly cooled down therein and is hardened thereby. In this context, this is also referred to as press-hardening of the workpieces.

[0003] Such a hot forming system and a method for producing hot formed, hardened workpieces is known from DE 100 49 660 A1, for example. The workpieces are here hardened in the drawing press by quickly being cooled down below a predetermined limit temperature. However, after leaving the drawing press, the temperature of the workpieces is still too high to be able to immediately further process the workpieces or to be able to handle them without problems. After the press-hardening, the workpieces are thus transferred to a fixing tool or gradually to a plurality of fixing tools which are connected in a row. The formed workpieces are fixed in the fixing tools and are thereby further cooled down. For this, a cooling medium can be used for cooling the fixing tool or for directly cooling the workpieces. When the temperature of the workpieces has decreased sufficiently, they can be fed to a further treatment.

[0004] In the case of the known method, the clock cycles of the drawing press can be reduced by the at least one fixing tool which is connected downstream from the drawing press. However, there is a further need for optimization for reducing the production costs of hot formed and hardened workpieces, for instance as vehicle body component.

[0005] The invention is thus based on the object of embodying and further developing a method and a hot forming system such that in particular high quantities of hardened, hot formed workpieces can be produced in a more cost-efficient manner.

[0006] This object is solved according to claim 1 by means of a method, wherein the formed workpiece is introduced into at least one hardening device, wherein the formed workpiece is fixed and calibrated, if need be, in a receiver of the hardening device which is adapted to the geometry of the formed workpiece, and wherein the formed workpiece is at least partially hardened in the receiver by means of a direct heat exchange with a cooling medium.

[0007] In the case of a hot forming system according to the preamble of claim 10, the object is furthermore solved in that a hardening device is provided for hardening the workpiece, in that a transfer device is provided for transferring the formed workpiece from the drawing press to the hardening device, in that the hardening device comprises a receiver for fixing the formed workpiece which is adapted to the geometry of the formed workpiece, and in that the receiver is adapted for at least partially hardening the formed workpiece by means of direct heat exchange with a cooling medium.

[0008] To produce a hot formed and hardened workpiece, a workpiece blank is thus initially brought to the required forming temperature in a furnace. The forming temperature is to be reached depending on the desired structure composition of the workpiece prior to and after the hardening. In particular a pre-cut piece of sheet steel can also be considered as workpiece blank. Such a pre-cut piece is also referred to as blank. The blank or the semifinished part, respectively, can be embodied monolithically but also as a tailored blank, which combines steels comprising different thicknesses and/or qualities.

[0009] After it has been heated to the forming temperature, the workpiece blank is transferred to a drawing press by means of a transfer device, which is provided for this purpose. In the drawing press, the workpiece blank is then formed in a manner known per se. A so-called drawn component or molded component is created. For this, the workpiece blank is preferably brought between two drawing tools, which are pressed against the workpiece blank from both sides under high pressure. The drawing tools are a female part and a male part, for instance.

[0010] The hot formed workpiece can cool down to a certain degree in the drawing press. The formed workpiece, however, is not hardened in the drawing press. After forming the workpiece is removed from the drawing press and is transferred to a hardening device by means of a further transfer device. In doing so, the formed workpiece is received in a receiver of the hardening device, the geometry of which is adapted to the geometry of the formed workpiece, so that the formed workpiece is fixed in the receiver during the hardening. For this purpose, the formed workpiece does not have to have full surface contact with the receiver.

[0011] The workpiece is at least partially hardened in the receiver, namely substantially by means of a direct heat exchange with a cooling medium. For this purpose the receiver is embodied such that the cooling medium can come into direct contact with the formed workpiece. It is thus not so much the receiver as such, which is cooled, but rather the workpiece.

[0012] According to the invention, a spatial and chronological separation is provided between the forming of the workpiece blank and the hardening of the formed workpiece. These two process steps are carried out in different system parts by means of different tools. Even though the system and procedural effort is increased through this, shorter clock cycles can thus be realized for the production of the hot formed and hardened workpieces as a whole, whereby the cost effectiveness of the production of hot formed and hardened workpieces as a whole improves.

[0013] The workpieces do not have to remain in the drawing press any longer than necessary. The drawing press can thus be operated at higher clock cycles in a more cost-efficient manner. As compensation, the formed workpieces are transferred to a hardening device for hardening. Due to the fact that
a further forming of the workpieces does not take place in the hardening device, the hardening device can be embodied to be simpler and more cost-efficient than the drawing press. The direct heat exchange between the cooling medium and the formed workpiece furthermore allows for the saving of time, preferably with reference to the hardening and possibly to the further cooling down to a temperature which does not impede the further handling of the workpieces.

In a further embodiment of the method, the quality of the material can be improved in that the workpiece blank is initially pre-cooled in air after leaving the furnace and prior to the introduction into the drawing press. The pre-cooling in air can preferably last for approximately 4 to 10 seconds, in particular 5 to 7 seconds. Within the afore-mentioned limits, this pre-cooling in air does not have a negative impact on the desired characteristics to be set in the finished component.

In a further embodiment of the method, the hot forming system can comprise a plurality of drawing presses, wherein the workpiece blank is gradually formed in the drawing presses. In so doing, workpieces comprising extensive geometric structures can be produced as well. However, it lends itself thereby when the workpiece is quickly transferred from drawing press to drawing press and only remains in the drawing presses for short clock cycles. The temperature of the formed workpiece is then still high enough to be hardened in the hardening device by means of a quick cooling. Preferably, the temperature of a workpiece, which is to be hardened and which is to comprise a substantially martensitic structure, lies at \( \geq M_s + 10K \) (\( M_s \) = martensite start). The quick cooling, which lies above the critical cool-down rate, leads to high strengths in the component, when cooling down to a temperature of below 250° C., preferably \( M_f \) (\( M_f \) = martensite finish).

According to a particularly preferred embodiment of the method, cooling medium flows at least partially around the formed workpiece in the receiver of the hardening device. The cooling medium is thus preferably conveyed in sections along the workpiece located in the receiver. A large quantity of heat can thus be removed from the workpiece within a short period of time.

With reference to the device, it is particularly preferred in this context when the receiver of the hardening device comprises ducts and/or bores, through which the cooling medium can flow. These ducts and/or bores are here provided such that they provide for the at least partial hardening of the formed workpiece by means of direct heat exchange with the cooling medium. On the one hand, the cooling medium is preferably guided through ducts and/or bores to the workpiece or to certain sections of the workpiece, respectively. On the other hand, the cooling medium is preferably removed again through other ducts and/or bores after contact with the workpiece.

The use of ducts and/or bores allows for a specific flow of the cooling medium, wherein also only certain areas of the workpiece can also be brought into contact with the cooling medium. Only certain areas of the workpiece can thus be hardened, for example, while other areas remain unhardenened due to a lower and/or slower cool-down.

In a structurally simple manner, the ducts and/or the bores are embodied such that the workpiece located in the receiver closes the ducts and/or bores at least on one side.

In a further preferred embodiment of the hot forming system, the receiver is embodied such that a contact surface between workpiece and receiver is always provided at least on one side of the workpiece. The workpiece can thus be continuously fixed in the receiver—even if more or less one-sidedly.

In the alternative or additionally, provision can be made for a duct and/or a bore to always be provided in the receiver, at least on one side of the workpiece. The workpiece can thus analogously be cooled constantly—even if more or less one-sidedly.
[0028] It is particularly advantageous in this context when a contact surface of the receiver is in each case assigned to the ducts and/or the bores of the receiver substantially opposite thereto, that is, on the other side of the workpiece.

[0029] In the alternative or in addition, the receiver can here comprise two halves, which comprise ducts and/or bores. Provision can thus be made on each side of the workpiece for alternating ducts and/or bores as well as for contact surfaces between the workpiece and the receiver. This serves for an even, cooling down and/or an even fixing of the workpiece.

[0030] In the event that the workpiece is not to be cooled down uniformly, provision can be made for only certain areas, preferably the areas which are to be hardened, to be quickly cooled down by means of direct heat exchange with the cooling medium. The remaining areas, for instance the areas which are not to be hardened preferably do not come into direct contact with the cooling medium, whereby the workpiece cools down more slowly there.

[0031] In this case, provision can only be made in the areas which are to be cooled down or hardened quickly, respectively, at least on one side of the workpiece for ducts and/or bores in the receiver. A contact surface of the receiver can further preferably be arranged so as to be located opposite to each duct and/or each bore of the receiver, that is, on the other side of the workpiece. In the remaining areas, i.e. at the sections of the workpiece which do not cool down so quickly, the workpiece is preferably fixed from both sides by means of contact surfaces between the receiver and the workpiece.

[0032] A further chronological and cost-related optimization of the method for producing hot formed and hardened workpieces can be obtained, if need be, when the formed and hardened workpiece was introduced into a cutting device and is cut therein at least partially, immediately after it was removed from the hardening device. This additional process step can thus preferably be integrated into the method and can thus be carried out in-line, because time is saved by means of the acceleration of the process steps which precede the cutting. A spatially and chronologically uncoupled method for cutting the workpiece is then not necessary. The definition of the term “cut” can be viewed as round, partial and/or hole cutting as a separating operation, for example.

[0033] In the alternative or in addition, provision can be made for the workpiece to be at least partially cut during the forming, thus in not least during the drawing process. In so doing, synergies can be created or used, respectively. In so doing, the cutting can at least partially also be carried out at a point in time in which the workpiece is still unhardened.

[0034] Contrary to the remaining sections of the workpiece, the sections of the workpiece which are to be cut may not be hardened in the hardening device, if required. The cutting of the workpiece after the hardening of the formed workpiece can thus be simplified and a service live for a higher quantity of workpieces can be attained in the cutting device.

[0035] For this purpose, the sections or areas which are to be cut and which are not to be hardened, can be kept away from the cooling medium in the hardening device. A direct heat exchange with the cooling medium thus does not take place at the mentioned sections.

[0036] To additionally or alternatively avoid an increased cooling down of the sections which are to be cut and/or of the areas of the workpiece which are not to be hardened during the forming thereof it is possible to not bring these sections and/or areas into contact with the drawing tools or to only bring them into a slight contact therewith. In other words, it is possible for the sections which are to be cut and/or the areas which are not to be hardened to not be pressed between the drawing tools in the drawing press or only slightly, thus preferably partially.

[0037] The invention aims at a hardening of the workpiece so as to set high strengths in the finished component. The areas which are to be hardened at least partially or the areas which are to be hardened and tempered, respectively, do not necessarily have to have a substantially martensitic structure, but another structure can also be set, for example bainite or a mixed structure, which provides for an increase of the toughness in response to reduced strength. The specific setting of the structure can be carried out via the parameters of the hardening device, such as temperature and flow rate of the cooling medium, for example.

[0038] The invention will be defined in more detail below by means of a drawing, which only illustrates exemplary embodiments.

[0039] FIG. 1 shows an exemplary embodiment of a hot forming system according to the invention.

[0040] FIG. 2 shows a temperature-time-diagram for a first exemplary embodiment of the method according to the invention.

[0041] FIG. 3 shows a temperature-time-diagram for a method which is known from the state of the art.

[0042] FIGS. 4a-4d show tools of the hot forming system according to FIG. 1 in a schematic illustration, and

[0043] FIGS. 5a-5b show a schematic detailed illustration of the receiver of the hardening device from FIG. 1.

[0044] FIG. 1 illustrates schematically a hot forming system 1 for carrying out a method for producing a hot formed and hardened workpiece 2. This workpiece 2 can be a vehicle body component, such as a chassis arm, side impact beam, bumper bracket, B column, A column or roof frame.

[0045] The hot forming system 1 comprises a punching press 3 for separating sheet steel cuts, so-called blanks, from a sheet steel strip. The sheet steel strip S is unwound from a coil C and consists of manganese-boron steel, preferably (AISI-22MnB5). However, other sheet steels as well as other surface coatings which are organic and/or metallic (zinc-based) are also possible.

[0046] A transfer device 4, which is embodied as a robotic arm in the illustrated hot forming system 1, successively introduces the workpiece blanks 2' in the form of blanks, which are buffered on a stack, into a furnace 5, which is a roller hearth furnace. The workpiece blanks 2' are heated in the furnace 5 to a forming temperature, which is higher than the austenitization temperature of the material of the workpiece blank 2'. In the case of the illustrated method, the austenitization temperature is at least approx. 730° C. The conversion of the manganese-boron sheet steel from ferrite to austenite takes place between approx. 730° C. and approx. 830° C. To ensure a reliable austenitization of the workpiece blank 2' and a reliable hardening of the formed workpiece 2, the workpiece blank 2' is heated in the furnace 5 to a forming temperature of 880° C.-950° C.

[0047] When heating the workpiece blank 2', it can be held at the austenitization temperature for a certain time (holding time), so as to ensure an even conversion into austenite. If need be, this can also be attained by using a plurality of furnaces through which the workpiece blank runs successively.
The workpiece blank 2' heated to the forming temperature is transferred to a drawing press 7 by means of a further transfer device 6 in the illustrated hot forming system 1. In turn, the transfer device 6 is a robotic arm. However, other transfer devices are also possible. During the transfer from the furnace 5 to the drawing press 7, the workpiece blank 2' is pre-cooled for approximately 6 seconds in air, wherein the temperature of the workpiece blank 2' is decreased to approx. 820°C.

The flat workpiece blank 2' is formed in the preferably hydraulically operated drawing press 7, in that the workpiece blank 2' is pressed in the drawing press 7 between two drawing tools 8, 9, a male part and a female part. During the forming of the workpiece 2 the temperature thereof can decrease to a more or less considerable extent by heat dissipated to the drawing tools 8, 9. In the illustrated hot forming system 1, the drawing tools 8, 9 are not forcedly cooled via a cooling medium or the like.

After the forming the workpiece 2 is passed on to a hardening device 10 by a transfer device (not illustrated). This transfer device, in turn, can be embodied as a robotic arm or as another device. The workpiece 2 is received in the hardening device 10 in a receiver 11 which consists of two halves 12, 13. The two halves 12, 13 interact such that the workpiece 2 is fixed in the closed receiver 11, so that the formed workpiece 2 cannot deform during hardening.

The workpiece 2 is hardened in the receiver 11 by means of direct contact and thus by means of direct heat exchange with a cooling agent (not illustrated). Ducts 14 and bores 15, 15' are introduced in the upper as well as in the lower half 12, 13 of the receiver 11 so as to guide the cooling medium to the surface of the workpiece 2 and to discharge it again after the heat exchange has taken place. In the case of the illustrated method, the workpiece is cooled down from approx. 520°C to below 200°C in the hardening device 10 in approximately 4 seconds.

In the illustrated hot forming system 1, the hardened, formed workpiece 2 is passed on to a cutting device 16. Parts of the workpiece 2 are cut there. The temperature of the workpiece 2 further decreases in the cutting device 16 by means of heat dissipated to the air and the cutting device 16.

The temperature profile of the workpiece 2 is illustrated in Fig. 2 as a temperature time diagram during some of the above-described process steps. This temperature profile serves for a better illustration. On principle, deviations from this temperature profile are possible with reference to time as well as with reference to the temperatures of the workpiece 2 during the individual processing steps.

In the case of the temperature profile illustrated in Fig. 2, the workpiece blank 2' is initially heated to a temperature of approx. 900°C. This heating phase of the workpiece blank 2' is not illustrated in the temperature time diagram. As required the heating phase can be carried out with a steadily decreasing temperature gradient or with a constant temperature gradient. It is also possible for the temperature of the workpiece blank 2' to be held over a certain period of time during the heating, for instance in the transition range to the austenite of approx. 730°C to 830°C.

A pre-cooling phase I in which the workpiece blank 2' cools down in air from approx. 900°C to approx. 820°C in approximately 6 seconds, then follows the heating phase before the workpiece blank 2' is formed in the drawing press 7. During the forming phase II the temperature drops to approx. 520°C in approx. 2 seconds. The transfer phase III of the workpiece 2 into the hardening device 10 which lasts approximately 3 seconds only slightly cools down the formed workpiece 2 further. In the subsequent hardening phase IV, however, a quick cool-down of the workpiece 2 to approx. 180°C takes place which is completed in approximately 4 seconds. Subsequently, provision is made for another phase V in which the workpiece 2 is transferred to a cutting device 16 and is cut there. This phase lasts approximately 4 more seconds. The temperature of the workpiece 2, however, only changes marginally in this period. Approximately 19 seconds after the removal from the furnace 5, the workpiece 2 can thus already be released to a processing system in a completely cut manner.

Fig. 3 illustrates a temperature profile of a workpiece which is processed in a conventional manner as temperature time diagram. In the case of this method, the workpiece blank 2' is heated to a temperature of approx. 900°C, so as to be formed approximately 7 seconds after the removal from the furnace. A cutting of the workpiece 2 has not yet taken place in the period of time. This requires a separate method.

Figs. 4a to 4d illustrate the individual tools of the hot forming system 1 illustrated in Fig. 1. The furnace 5, in the furnace chamber 17 of which a flat workpiece blank 2' is introduced so as to be heated to forming temperature, is schematically illustrated in Fig. 4a. It is a sheet steel blank. Fig. 4b illustrates the drawing tools 8, 9 of the drawing press 7. The drawing tools 8, 9 are located in an open position. The male part forms the workpiece blank 2' around the female part and thus creates a workpiece 2 in the form of a molded component or drawn component, respectively. Fig. 4c illustrates the two halves 12, 13 of a receiver 11 of a hardening device 10 which will be described in more detail below. Fig. 26 illustrates a cutting device 16, in which the two outer ends of the formed and hardened workpiece 2 are cut.

The receiver 11 of the hardening device 10 is illustrated in Figs. 5a and 5b in an open and in a closed position. The receiver 11 consists of an upper and a lower half 12, 13. The receiver could also consist of a plurality of parts or could be embodied in one piece. On both halves 12, 13 of the receiver 11 ducts 14 are provided which are open towards the outside. In the closed position of the receiver 11 these ducts 14 are closed by means of the workpiece 2 received therein, so that a cooling medium can circulate in the ducts 14. The cooling medium is supplied and discharged again via bores 15, 15' which are only illustrated schematically and which are connected to the ducts 14. The sections of the workpiece 2 which do not close a duct 14 provided in the receiver 11 shut on contact surfaces 18 of the receiver 11 or on one of the halves 12, 13 of the receiver 11.

The ducts are provided so as to be distributed only in an area 19 of the workpiece 2 to be hardened. The edges 20 of the workpiece 2 are not hardened. The workpiece 2 does not come into contact with the cooling medium at that location. However, in the area 19 which is to be hardened the workpiece 2 is in contact with the cooling medium in the closed position of the receiver 11 and with ducts 14 filled with cooling medium, at least from one side, thus from the top or from
below. In the area 19 which is to be hardened the workpiece 2 is thus cooled everywhere either from the top or from the bottom through direct heat exchange with the cooling medium.

[0060] On the other half 13, 12 of the receiver 11, contact surfaces 18 are located opposite to the ducts 14 of the one half 12, 13 of the receiver 11. In the area 19 to be hardened the workpiece 2 is quasi fixed in the receiver 11 via the contact surfaces 18 either from the top or from the bottom. The workpiece 2 rests in each case continuously against the contact surfaces 18 of both halves 12, 13 of the receiver 11 at the edges 20, i.e. in the areas of the workpiece 2 which are not to be hardened.

[0061] On principle, embodiments of the receiver, which deviate from the receiver illustrated in FIGS. 5a and 5b and which were described in detail above can also be considered.

1. A method for producing a hardened, hot formed workpiece from sheet steel, comprising:
   at least partially heating a workpiece blank in at least one furnace to a forming temperature;
   introducing the heated workpiece blank into at least one drawing press;
   forming the heated workpiece blank into a workpiece in the at least one drawing press;
   introducing the formed workpiece into at least one hardening device;
   fixing the formed workpiece in a receiver of the hardening device, which is adapted to the geometry of the formed workpiece: and
   at least partially hardening the formed workpiece in the receiver by means of direct heat exchange with a cooling medium.

2. The method according to claim 1, wherein the workpiece blank is heated to a forming temperature which exceeds the austenitization temperature of the workpiece blank.

3. The method according to claim 1, wherein the heated workpiece blank is pre-cooled in air prior to the introduction into the drawing press.

4. The method according to claim 1, wherein the workpiece blank is gradually formed into a workpiece in a plurality of drawing presses.

5. The method according to claim 1, wherein cooling medium flows at least partially around the formed workpiece in the receiver of the hardening device.

6. The method according to claim 1, wherein the formed and hardened workpiece is introduced into a cutting device immediately after removal from the hardening device and is at least partially cut therein.

7. The method according to claim 1, wherein the workpiece is at least partially cut during forming.

8. The method according to claim 6, wherein sections of the workpiece which are to be cut are not hardened in the hardening device.

9. The method according to claim 8, wherein sections of the workpiece which are to be cut are kept away from the cooling medium in the hardening device.

10. The method according to claim 6, wherein the sections of the workpiece, which are to be cut, are at most slightly brought into contact with drawing tools of the at least one drawing press.

11. A hot forming system for producing a hardened formed workpiece of steel,
   comprising: a furnace for at least partially heating a workpiece blank to a forming temperature;
   comprising a drawing press for forming the workpiece blank;
   comprising a transfer device for transferring the heated workpiece blank from the furnace to the drawing press;
   a hardening device for hardening the workpiece; and
   a transfer device for transferring the formed workpiece from the drawing press to the hardening device,
   wherein the hardening device comprises a receiver is adapted to the geometry of the formed workpiece for fixing the formed workpiece, and
   for at least partially hardening the formed workpiece by means of direct heat exchange with a cooling medium.

12. The hot forming system according to claim 11, wherein the receiver comprises ducts, bores, or a combination thereof for at least partially hardening the formed workpiece by means of direct heat exchange with the cooling medium.

13. The hot forming system according to claim 11, wherein the receiver comprises a contact surface for the formed workpiece at least on one side of the formed workpiece.

14. The hot forming system according to claim 11, wherein the receiver comprises two halves comprising ducts, bores, or a combination thereof and in areas of the workpiece provided for hardening, contact surfaces for the formed workpiece of the one half are arranged opposite to the ducts, bores, or combination thereof of the other half.

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