

(19)



(11)

EP 4 826 006 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

21.10.2026 Bulletin 2026/43

(51) International Patent Classification (IPC):

C22C 38/00 ^(2006.01) **C21D 1/18** ^(2006.01)
C21D 1/30 ^(2006.01)

(21) Application number: **26166973.3**

(52) Cooperative Patent Classification (CPC):

C21D 1/18; C21D 1/30; C22C 38/00;
C21D 2211/008; C21D 2221/00

(22) Date of filing: **24.03.2026**

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR

Designated Extension States:

BA

Designated Validation States:

GE KH LA MA MD TN

(72) Inventors:

- **Yu, Kenneth K**
Clarkston (US)
- **Yu, Huaxia**
Okemos (US)

(74) Representative: **Whitfield, Jack Stephen**

Withers & Rogers LLP
2 London Bridge
London SE1 9RA (GB)

(30) Priority: **14.04.2025 US 202519178058**

(71) Applicant: **ArvinMeritor Technology, LLC**
Troy, MI 48084 (US)

(54) **IMPROVED HEAT TREAT PROCESS**

(57) A heat treat process for a metal part and a metal part made by the heat treat process is provided. The heat treat process includes providing a metal material having a shape including an outer contour. Then, heating the metal material above a critical temperature of the metal material. Further, cooling the heated metal material in at least one preselected first region of the outer contour to maintain the temperature of the preselected first region below the critical temperature and

leaving the heated metal material in a remaining second region of the outer contour outside the preselected first region above the critical temperature. Then, quenching the heated metal material to form the second regions having a primarily martensitic microstructure and the preselected first regions having a less martensitic microstructure than the second regions. Further, finish forming the quenched metal material to finish the metal part.

EP 4 826 006 A1

Description

PRIORITY INFORMATION

[0001] This application claims priority to United States of America Patent Application 19/178,058 filed at the USPTO on 14 April 2025 entitled Improved heat treat process and parts resulting therefrom.

TECHNICAL FIELD

[0002] The present disclosure relates to a heat treat process, and more particularly to a rapid quench heat treat process with localized cooling and parts resulting therefrom.

BACKGROUND

[0003] It is known to heat treat metal, such as after being machined or forged, in a heat treat process during the production of a metal part. Typically, the heat treat process includes an annealing step, wherein the metal is heated to a temperature above a critical temperature to refine microstructure and reduce internal stresses. Then, the metal is heated above its critical temperature to homogenize an austenitic microstructure and then rapidly quenched in a quenching process to harden the entirety of the metal to contain primarily martensitic microstructure. Then, the hardened metal is tempered to reduce the hardness and increase the ductility of the metal, thereby rendering the metal less brittle. Then, the metal is induction hardened to form a hardened outer layer on the part, followed by a tempering process to reduce internal stresses of the metal. The process then typically includes a re-centering process to straighten the part after going through the prior heating and cooling processes. Then, the part may be finished in a machining operation, such as a turning.

[0004] Although the aforementioned heat treat process may produce metal parts as desired, the process is laborious, time extensive, and costly. Further, the parts may result in excessive internal stresses and cracking, such as from the rapid quench process, thereby resulting in a part having cracks prone to crack propagation, thereby resulting in the part having a relatively short useful life or a part subject to premature failure.

SUMMARY

[0005] In accordance with one aspect of the disclosure, a heat treat process for a metal part is provided. The heat treat process includes providing a metal material having a shape including an outer contour. Then, heating the metal material above a critical temperature of the metal material. Further, cooling the heated metal material in at least one preselected first region of the outer contour to reduce the temperature of the pre-

lected first region below the critical temperature and leaving the heated metal material in a remaining second region of the outer contour outside the preselected first region above the critical temperature. Then, quenching the heated metal material.

[0006] The method may further include finish forming the quenched metal material to form the metal part.

[0007] The method further includes providing the at least one preselected first region with a first hardness and providing the remaining second region having a second hardness, with the first hardness being less than the second hardness.

[0008] The method further includes providing the metal material as a ferrous-alloy.

15 [0009] The method further includes forming austenite in the ferrous-alloy upon heating the metal material above the critical temperature.

[0010] The method further includes providing the at least one preselected first region having a less martensitic microstructure than the second region after the quenching process.

20 [0011] The method may further include providing the second region being primarily martensitic after the quenching process.

25 [0012] The method may further include tempering the quenched ferrous-alloy material.

[0013] The method may further include cooling the heated metal material in the at least one preselected first region while heating the metal material.

30 [0014] The method may further include cooling the heated metal material in the at least one preselected first region after heating the metal material above the critical temperature and before quenching the heated metal material.

35 [0015] In accordance with another aspect of this disclosure, a heat treat process for a metal part is provided. The process may include providing a ferrous-alloy metal having a shape including an outer contour and heating the metal material in a succession of heat cycles with a dwell cycle intervening between successions of the heat cycles and selectively cooling the heated metal material in the at least one preselected first region during at least one of the dwell cycles before quenching the heated metal material. The method may further include maintaining a temperature of a remaining second region of the outer contour, different than the at least one preselected first region, above the critical temperature. The method may further include quenching the heated ferrous-alloy material.

50 [0016] The method may further include cooling the heated metal material in the at least one preselected first region via a gas medium.

[0017] The method may further include cooling the heated metal material in the at least one preselected first region via a liquid medium.

55 [0018] The method may further include cooling the heated metal material in the at least one preselected first region via an airborne mist medium.

[0019] The method may further include cooling the heated metal material in the at least one preselected first region by spraying a jet stream of cooling medium onto the at least one preselected first region.

[0020] The method may further include heating the metal material above the critical temperature via an induction heating process.

[0021] The method may further include heating the metal material above the critical temperature in a furnace.

[0022] The method may further include cooling the heated metal material in a plurality of preselected first regions spaced from one another by the remaining second region.

[0023] The method may further include selecting the at least one preselected first region as a region prone to cracking during the quenching.

[0024] In accordance with another aspect of the disclosure, a metal part is provided that is heat treated via the aforementioned heat treat process.

[0025] In accordance with another aspect, the metal part may be a ferrous-alloy, wherein the at least one preselected first region has a first martensitic microstructure and the second region has a second martensitic microstructure, wherein the first martensitic microstructure is a less martensitic microstructure than the second martensitic microstructure.

[0026] In accordance with another aspect, the at least one preselected first region of the metal part includes a plurality of preselected first regions spaced from one another by an intermediate second region.

[0027] In accordance with another aspect, the at least one preselected first region of the metal part includes a blind bore.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

FIG. 1 is a process flow diagram of a heat treat process for a metal material in accordance with an aspect of the disclosure;

FIG. 2 is side elevation view of a metal part being heat treated via the heat treat process in accordance with the disclosure; and

FIG. 3 is side elevation view of a finished metal part heat treated via the heat treat process in accordance with the disclosure.

DETAILED DESCRIPTION

[0029] Embodiments of the present disclosure are described herein. It is to be understood, however, that the disclosed embodiments are merely examples and other embodiments can take various and alternative forms. The figures are not necessarily to scale; some

features could be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative bases for teaching one skilled in the art to variously employ the embodiments. As those of ordinary skill in the art will understand, various features illustrated and described with reference to any one of the figures can be combined with features illustrated in one or more other figures to produce embodiments that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical application. Various combinations and modifications of the features consistent with the teachings of this disclosure, however, could be desired for particular applications or implementations.

[0030] "A", "an", and "the" as used herein refers to both singular and plural referents unless the context clearly dictates otherwise. By way of example, "a processor" programmed to perform various functions refers to one processor programmed to perform each and every function, or more than one processor collectively programmed to perform each of the various functions.

[0031] The term "substantially" or "about" may be used herein to describe disclosed or claimed embodiments. The term "substantially" or "about" may modify a value or relative characteristic disclosed or claimed in the present disclosure. In such instances, "substantially" or "about" may signify that the value or relative characteristic it modifies is within $\pm 0\%$, 0.1% , 0.5% , 1% , 2% , 3% , 4% , 5% or 10% of the value or relative characteristic.

[0032] Although the terms first, second, third, etc. may be used to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as "first," "second," and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0033] Spatially relative terms, such as "inner," "outer," "beneath," "below," "lower," "above," "upper," and the like, may be used for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the

other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0034] Traditional heat treat processes for metal parts, such as those used in vehicle components, involve heating the entire metal part above its critical temperature and then rapidly quenching it to achieve a hardened, primarily martensitic microstructure. While this method can produce the desired hardness, it also introduces significant internal stresses and can lead to cracking, particularly in regions prone to stress risers such as sharp corners, grooves, and notches. These cracks can propagate, resulting in parts with reduced useful life and increased likelihood of premature failure. Additionally, the conventional process is labor-intensive, time-consuming, and costly, further complicating the production of durable metal parts.

[0035] The present disclosure addresses these shortcomings by providing a heat treat process that introduces selective cooling during the heating phase. In embodiments, a ferrous-alloy material is provided with a specific shape and outer contour. This material is heated above its critical temperature. A first region of the outer contour is selectively cooled to reduce the temperature of the first region below the critical temperature while maintaining the temperature of the remaining second region above the critical temperature. Then, the material is quenched and tempered.

[0036] These concepts are illustrated in the Figures as embodiments. As illustrated in FIG. 1 for example, a heat treat process 10 for a metal part 12 is provided. The heat treat process 10 includes a preparatory first process, referred to as process 1, identified by reference numeral 14. The first preparatory process can include providing a metal material 16 (FIGS. 2-3) having a shape including an outer contour. Then, the metal material 16 can be heated at heating 18a above a critical temperature of the metal material 16, wherein the critical temperature is defined by a temperature at which a phase of the metal material 16 changes. Further, the metal material 16 can be cooled at 18b in at least one preselected first region 20 to reduce or keep the temperature of the preselected first region 20 below the critical temperature, while leaving the heated metal material 16 in a remaining second region 22, outside the preselected first region 20, above the critical temperature. In other words, a heating and cooling control can occur that maintains the metal material 16 within a selected temperature range.

[0037] The temperature-controlled metal material 16 can then be subjected to quenching 24 to reduce the temperature of the entirety of the metal material 16 below the critical temperature. Then, subsequent process(es) including finish forming the metal material 16 in process 3, identified by reference numeral 26, to

form the finished metal part 12 (FIG. 3).

[0038] The metal material 16 can be provided of any metal material capable of being hardened via a heat treat process, such as a ferrous-alloy or aluminum, by way of example and without limitation. A person possessing ordinary skill in the art of metals and heat treat processes will readily understand such heat treatable metal materials and the associated critical temperature ranges for each such metal material. Accordingly, it is believed unnecessary to denote a wide range of possible critical temperatures for the various types of heat treatable metal materials herein, such as the numerous grades of steel, by way of example and without limitation. With steel used as an example, the step of heating 18a the metal material 16 above the critical temperature, known in the art as an Ac3 temperature, results in forming austenite in the ferrous-alloy, such that the material becomes austenitic, upon heating the metal material 16 above the critical temperature.

[0039] Further, the step of quenching the metal material 16 results in the at least one preselected first region 20, which is reduced in temperature below the critical temperature prior to quenching 24, having a less martensitic microstructure than the second region 22 after quenching 24. Accordingly, the second region(s) 22 will have more martensite than the first region(s) 20, with the second region(s) being primarily composed of martensite, with the second region(s) having possible retention of some austenite, bainite, and pearlite, for example, as will be understood by a skilled person in the art. As such, the at least one preselected first region(s) 20 has a first percent content by volume of martensitic microstructure and the second region(s) 22 has a second percent content by volume of martensitic microstructure, wherein the first percent content by volume of martensitic microstructure is less than the second percent content by volume of martensitic microstructure. Meanwhile, the first region(s) 20, having been cooled to below the critical temperature prior quenching 24, will contain a microstructure primarily of bainite, ferrite, pearlite, along with other transformation properties, as will be understood by a person possessing ordinary skill in the art of metallurgy, depending on the cooling rate employed during quenching 24. With the first region(s) 20 having a relatively reduced martensitic microstructure, the first region(s) are less prone to crack formation and propagation during the quenching 24 and thereafter. As such, the resulting metal part 12, as a result of the preselected first region(s) 20 being selectively cooled via cooling 18b during heating 18a to maintain the first region(s) 20 below the critical temperature prior to quenching 24, has first region(s) 20 free from quench cracks that could otherwise have occurred absent the cooling 18b during the heating 18a. Additionally, the preselected first region(s) 20 attain a first hardness, while the remaining second region(s) 22 attain a second hardness, with the first hardness being less than the second hardness.

[0040] In view of the material properties of the first region(s) 20 and the second region(s) 22, the selecting of the preselected first region(s) 20 is strategic to optimize the performance of the metal part 12 during use. In particular, the first region(s) are selected as region(s) most prone to cracking during the quenching 24. For example, as shown in FIG. 2, the preselected first regions 20 are selected as regions having stress risers, wherein a stress riser is known as being produced by at least one of a sharp corner, groove, notch, and acute change of section that causes local stress concentrations under load. As one example, the first regions 20 may include the groove near the top of the metal part in FIG. 2 may be a snap ring groove configured to receive a snap ring configured to retain another vehicle component to the metal part 12. The snap ring groove 20 may have a relatively sharp inner radius and/or outer radius that may range between 1.5 mm and 3 mm. As another example, the first regions 20 may include one or more apertures such as fluid (e.g., oil) passage holes that may be defined by end portions of the metal part 12 or disposed therebetween.

[0041] In the example metal part 12 illustrated, the preselected first regions 20 are selected at transition regions from splined regions 28 to reduced diameter regions 30, wherein these first regions 20 are more prone to crack formation during quenching 24. However, as a result of the cooling 18b discussed herein, crack formation in the first regions 20 is prevented, while allowing the desired hardening of the second regions 22, thereby resulting in a stronger part compared to a part not undergoing the cooling 18b prior to quenching 24. The non-limiting metal part 12 illustrated includes a plurality of preselected first regions 20 spaced from one another by the remaining second region 22, however, it is to be understood that any number and arrangement of first regions 20 and second regions 22 is contemplated herein, depending on the type of metal part 12 being made. The non-limiting metal part 12 illustrated is a drive shaft for a motor vehicle, by way of example and without limitation, wherein the splined second regions 22 facilitate the transfer of torque throughout a drive train, with the first regions 20 being able to withstand the transfer of torque without premature failure, due in large part to the aforementioned heat treat process 10. Experimental testing has shown that the cooling 18b of the first regions 20 increases fatigue performance and overall strength as compared to metal parts that do not undergo the cooling 18b. As one non-limiting example, fatigue performance increased by up to four-hundred percent. As another example, load capacity increased by up to one-hundred-thirty percent.

[0042] The metal part 12 may be processed via any number of processes in the process 1 step 14, such as forging, machining, stamping, or otherwise, depending on the type of metal part 12 being produced. The aforementioned process 1 steps 14 generally result in re-

tained internal stresses within the metal material 16, and thus, prior to the heating 18a and cooling 18b, the metal material 16 may be processed via an annealing step 32. Annealing is well understood by persons possessing ordinary skill in the art of heat treatment of metal parts, wherein the metal part is heated to a temperature below the melting point of the metal material 16 and then cooled slowly to cause the internal stresses to be reduced. Further yet, after annealing 32, and prior to heating 18a and cooling 18b, the metal material 16 may undergo a second process 2, identified by reference numeral 34. The second process 2 may include a machining and/or forming process, by way of example and without limitation, such as turning and rolling the splined regions 28. Of course, other features may be formed in the second process 2 34, as desired.

[0043] The heating step 18a and cooling step 18b may be performed in several different ways. For example, the cooling step 18b of the heated metal material 16 in the preselected first region(s) 20 may be performed while heating the metal material 16 above the critical temperature. Accordingly, the heating step 18a and the cooling step 18b may be performed concurrently. Further, the cooling step 18b for cooling the heated metal material 16 in the at least one preselected first region(s) 20 may be performed after heating the metal material 16 above the critical temperature in the heating step 18a, and before quenching 24 the heated metal material 16.

[0044] Accordingly, the heating step 18a may be performed first, and then the cooling step 18b may be performed afterward, but prior to quenching 24. Further, the heating step 18a for heating the metal material 16 above the critical temperature may be performed in a succession of repeated heat cycles with a dwell cycle, also referred to as pause cycle, intervening between successions of the heat cycles, with the cooling step 18b of the heated metal material 16 being performed during at least one, or each of the dwell cycles, and before quenching 24 the heated metal material 16. Further yet, the heating step 18a and cooling step 18b may be formed in an induction heating process, wherein coils 36 (FIG. 2) are energized to heat the metal part 12, and in one non-limiting embodiment, the metal part 12 may be rotated about a central longitudinal axis A while the coils 36 are being energized, and possibly deenergized during a cycle including the aforementioned dwell cycle(s). Otherwise, other heat treat mechanisms are contemplated, such as a furnace, by way of example and without limitation. As such, it is contemplated that the metal part(s) 12 may be heat treated individually or in batches, as desired.

[0045] The cooling step 18b may be performed via any suitable cooling medium 40. In one non-limiting embodiment, the cooling medium is a gas medium, such as air, but it is contemplated that a liquid medium, e.g. water, or airborne mist medium could be used. Further, the cooling step 18b may be performed by

spraying a jet stream of the cooling medium 40 via a jet nozzle(s), by way of example and without limitation, onto the at least one preselected first region(s) 20. In the example embodiment illustrated in FIG. 2, the jet nozzles 38 are oriented to spray the cooling medium 40 to impact the preselected first regions 20, shown as two preselected first regions 20 spaced axially from one another along the length of the metal part 12 by the intermediately located second region 22, with a third preselected first region 20 shown extending into an end of the metal part 12 as a blind bore extending along the longitudinal central axis A, by way of example and without limitation.

[0046] After heating/cooling 18a, 18b and then quenching 24, the metal part 12 may be routed through a tempering process 40 to alleviate internal stresses resulting from quenching 24 the metal material 16, particularly a ferrous-alloy material 16. Tempering is well understood by persons possessing ordinary skill in the art of heat treatment of metal parts, wherein the metal part is heated to a temperature below the critical temperature, and the propensity for cracking is reduced, and the hardness of the metal material 16 is reduced. Depending on the desired toughness and hardness, the temperature and length of time of temperature may be selected as desired.

[0047] Lastly, the finish forming of the metal material 16 in process 3 26 may be performed to finalize the shape and appearance of the metal part 12. For example, the finish forming process 3 26 may include polishing, honing, machining, plating, painting, or otherwise, as desired to complete manufacture of the finished metal part 12. A finished metal part 12 heat treated and processed in accordance with the heat treat process, the preparatory process(es) to heat treat, and subsequent process(es) to heat treat, all disclosed herein, is illustrated in FIG. 3.

[0048] While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms encompassed by the claims. The words used in the specification are words of description rather than limitation, and it is understood that various changes can be made without departing from the spirit and scope of the disclosure. As previously described, the features of various embodiments can be combined to form further embodiments of the invention that may not be explicitly described or illustrated. While various embodiments could have been described as providing advantages or being preferred over other embodiments or prior art implementations with respect to one or more desired characteristics, those of ordinary skill in the art recognize that one or more features or characteristics can be compromised to achieve desired overall system attributes, which depend on the specific application and implementation. These attributes can include, but are not limited to cost, strength, durability, life cycle cost, marketability, appearance, packaging, size, serviceability, weight, manufacturability, ease of

assembly, etc. As such, to the extent any embodiments are described as less desirable than other embodiments or prior art implementations with respect to one or more characteristics, these embodiments are not outside the scope of the disclosure and can be desirable for particular applications.

Claims

1. A heat treat process for a metal part, comprising:
 - providing a ferrous-alloy material having a shape including an outer contour;
 - heating the ferrous-alloy material above a critical temperature of the ferrous-alloy material;
 - selectively cooling at least one preselected first region of the outer contour to reduce the temperature of the preselected first region below the critical temperature;
 - maintaining a temperature of a remaining second region of the outer contour, different than the at least one preselected first region, above the critical temperature; and
 - quenching the heated ferrous-alloy material.
2. The heat treat process of claim 1, wherein the selectively cooling step includes providing the at least one preselected first region with a first hardness and the maintaining step includes providing the remaining second region having a second hardness, wherein the first hardness is less than the second hardness.
3. The heat treat process of claim 1 or claim 2, wherein the heating step includes forming austenite in the ferrous-alloy material upon heating the ferrous-alloy material above the critical temperature.
4. The heat treat process of any previous claim, wherein the selectively cooling step and the maintaining step include providing the at least one preselected first region having a less martensitic microstructure than the second region after the quenching process.
5. The heat treat process of any previous claim, wherein the selectively cooling step and the maintaining step include providing the second region being primarily martensitic after the quenching process.
6. The heat treat process of any previous claim, further comprising:
 - tempering the quenched ferrous-alloy material.
7. The heat treat process of claim 6, further comprising:

finish forming the quenched ferrous-alloy material to form the metal part.

8. The heat treat process of any previous claim, wherein the maintaining step includes heating the remaining second region of the outer contour. 5
9. The heat treat process of any previous claim, wherein the selectively cooling step is performed after the heating step and before the quenching step. 10
10. The heat treat process of any previous claim, wherein the ferrous-alloy material is heated above the critical temperature in a succession of heat cycles with a dwell cycle intervening between successions of the heat cycles. 15
11. The heat treat process of any previous claim, wherein the selectively cooling step includes spraying a jet stream of cooling medium onto the at least one preselected first region, optionally wherein the cooling medium is a gas medium and/or a liquid medium and/or a vapor medium, optionally wherein the selectively cooling step includes selectively cooling a plurality of preselected first regions spaced from one another by the remaining second region. 20 25
12. The heat treat process of any previous claim, wherein the heating step includes induction heating of the ferrous-alloy material and/or heating the ferrous-alloy material above the critical temperature in a furnace. 30 35
13. The heat treat process of any previous claim, further including selecting the at least one preselected first region as a region prone to cracking during the quenching. 40
14. A metal part configured for use in a vehicle, the metal part comprising:
a body formed of a ferrous-alloy material being heated above a critical temperature of the ferrous-alloy material and including: 45
at least one preselected first region being selectively cooled to reduce the temperature of the preselected first region below the critical temperature, 50
at least one preselected second region being maintained above the critical temperature as the first selected region is selectively cooled, wherein the at least one preselected first region has a first hardness and the at least one preselected second region has a second hardness, wherein the first hardness is less than the second hardness. 55

15. The metal part of claim 14, wherein the at least one preselected first region has a first percent content by volume of martensitic microstructure and the second region has a second percent content by volume of martensitic microstructure, wherein the first percent content by volume of martensitic microstructure is less than the second percent content by volume of martensitic microstructure.

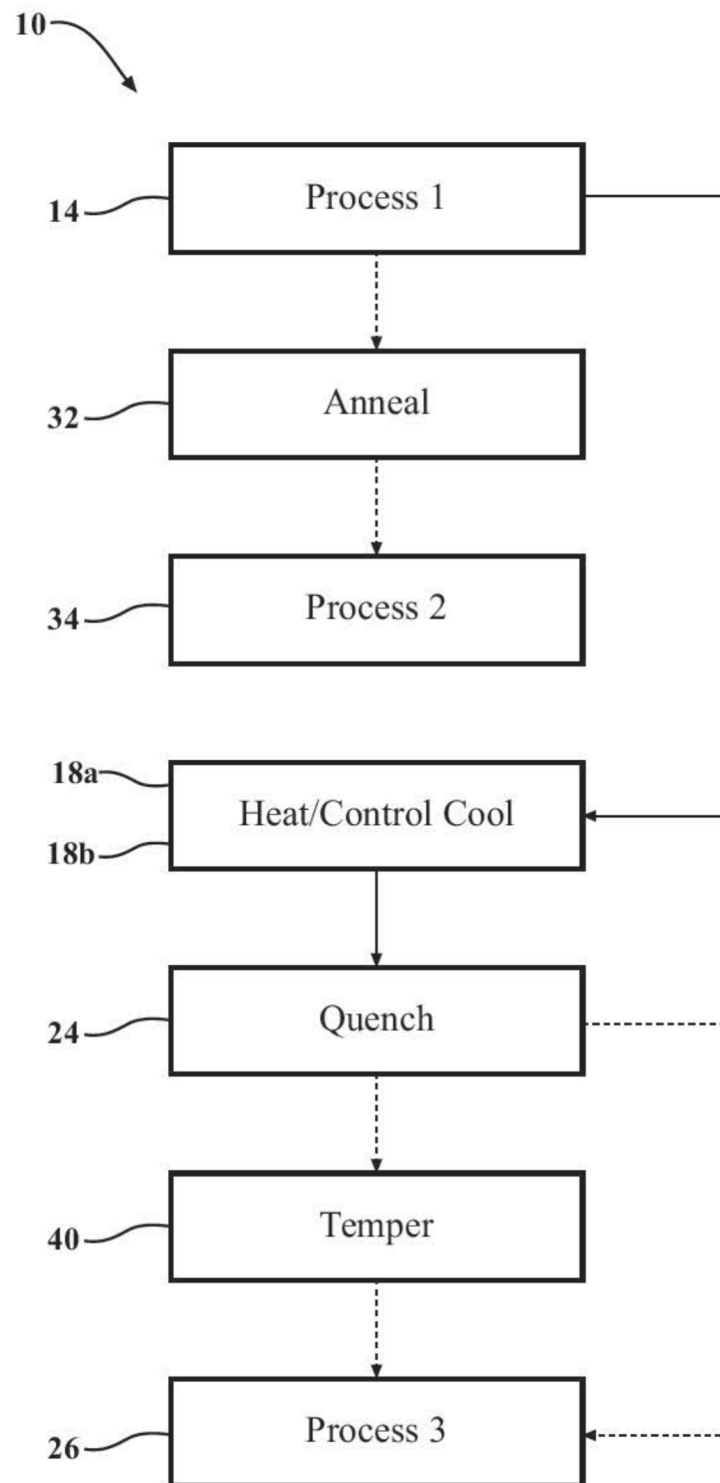


FIG. 1

FIG. 2

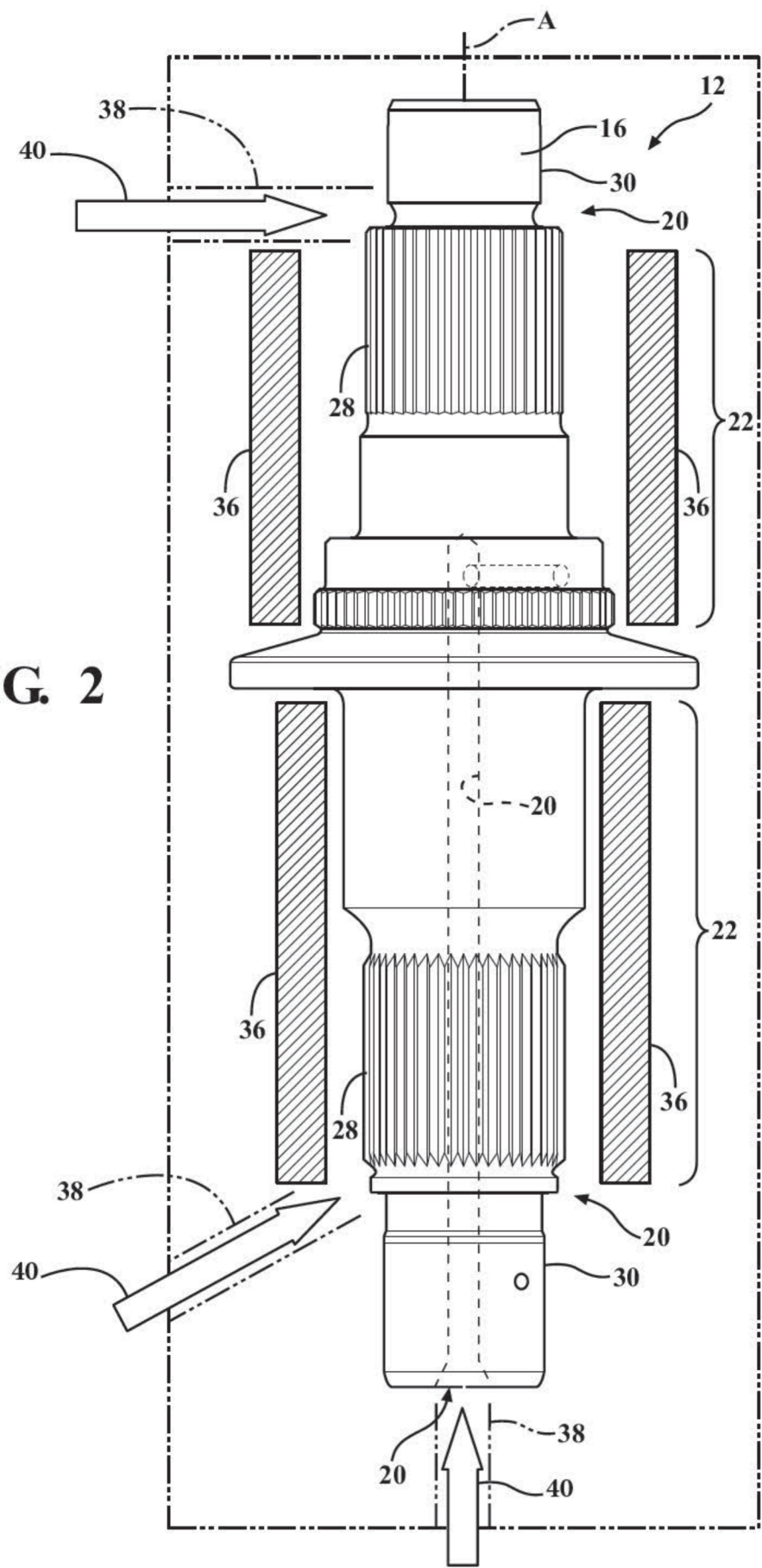
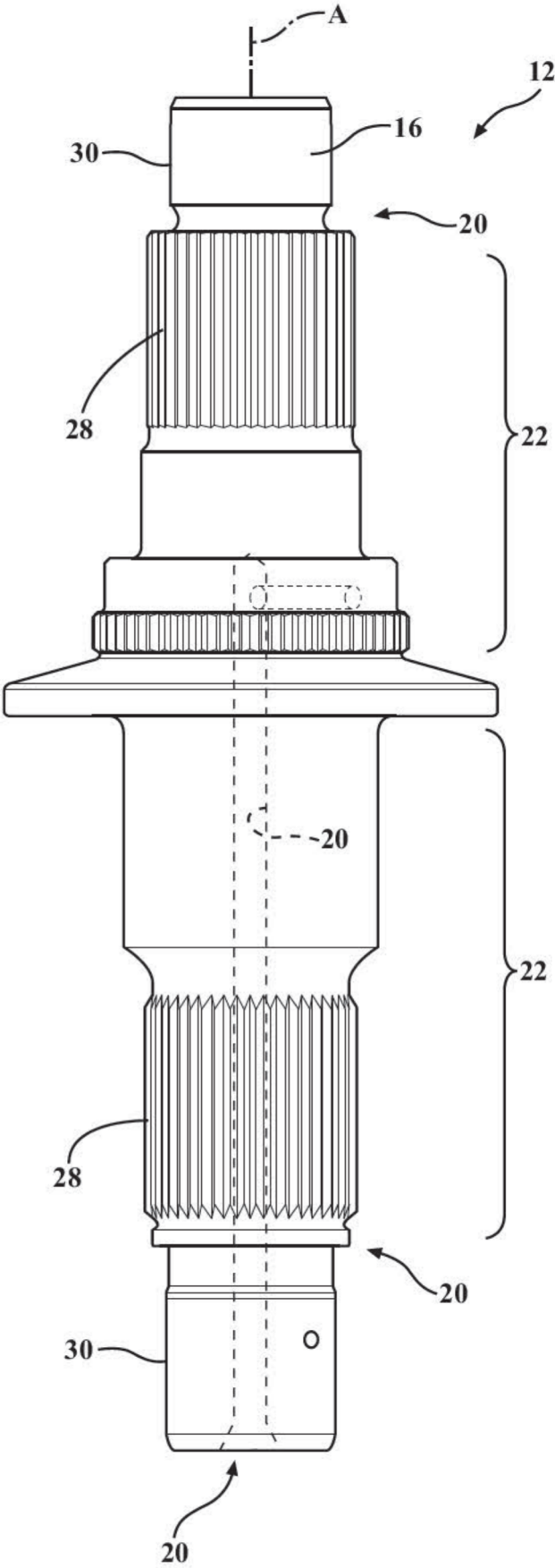


FIG. 3





EUROPEAN SEARCH REPORT

Application Number

EP 26 16 6973

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	DE 10 2021 131713 A1 (GM GLOBAL TECH OPERATIONS LLC [US]) 4 May 2023 (2023-05-04)	1-7,9, 10,12-15	INV. C22C38/00 C21D1/18 C21D1/30
A	* paragraphs [0064], [0068] - [0071]; claims 1-10; figure 5 *	8,11	
X	WO 2015/110456 A1 (SCHWARTZ GMBH [DE]) 30 July 2015 (2015-07-30) * claims 1-11 * * page 8, lines 8-23; figures 3, 4 *	1-15	
X	DE 10 2011 057007 A1 (BENTELER AUTOMOBILTECHNIK GMBH [DE]) 27 June 2013 (2013-06-27)	1-10, 12-15	
A	* paragraphs [0029], [0030], [0032], [0044]; claims 1-13 *	11	
X	NAKAGAWA YUKI ET AL: "Tailored tempering without die heating in hot stamping of ultra-high strength steel parts", MATERIALS & DESIGN ELSEVIER, AMSTERDAM, NL, vol. 192, 6 April 2020 (2020-04-06), XP086201350, ISSN: 0264-1275, DOI: 10.1016/J.MATDES.2020.108704 [retrieved on 2020-04-06]	1-10, 12-15	TECHNICAL FIELDS SEARCHED (IPC) C22C C21D
A	* sections 1, 4.2, 6; figure 15 *	11	
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		17 August 2026	Pircher, Ernst
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			



EUROPEAN SEARCH REPORT

Application Number

EP 26 16 6973

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	OTA EIICHI ET AL: "CAE-based process design for improving formability in hot stamping with partial cooling", JOURNAL OF MATERIALS PROCESSING TECHNOLOGY ELSEVIER, NL, vol. 263, 18 August 2018 (2018-08-18), pages 198-206, XP085475266, ISSN: 0924-0136, DOI: 10.1016/J.JMATPROTEC.2018.08.021	1-7,9-15	
A	* paragraph [0002]; figure 2 * -----	8	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
Place of search		Date of completion of the search	Examiner
The Hague		17 August 2026	Pircher, Ernst
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 26 16 6973

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

17-08-2026

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102021131713 A1	04-05-2023	CN 116065004 A	05-05-2023
		DE 102021131713 A1	04-05-2023
		US 2023140215 A1	04-05-2023

WO 2015110456 A1	30-07-2015	DE 202014010318 U1	01-04-2015
		EP 2905346 A1	12-08-2015
		ES 2828179 T3	25-05-2021
		HU E051924 T2	29-03-2021
		PL 2905346 T3	08-03-2021
		WO 2015110456 A1	30-07-2015

DE 102011057007 A1	27-06-2013	CN 103173606 A	26-06-2013
		DE 102011057007 A1	27-06-2013
		US 2013160906 A1	27-06-2013

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 17805825 [0001]