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(54) **Method for producing gears and/or shaft components with superior bending fatigue strength and pitting fatigue life from conventional alloy steel**

Verfahren zur Herstellung von Getrieben und/oder Achsen, die verbesserte Biegedauerfestigkeit und Dauerlochfrassfestigkeit als bisherige legierte Stähle aufweisen.

Procédé pour produire des engrenages et/ou des arbres présentant une résistance a la fatigue en flexion et a la fatigue piqures supérieure à celle des aciers conventionelles.

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Description

FIELD OF INVENTION

[0001] This invention relates to achieving both superior Bending fatigue strength and Pitting fatigue life of gear(s) and/or shaft components, using "conventional alloy steel" by a particular method.

[0002] US-6,447,619 discloses special steels with 0.3 to 3.0 weight % Aluminium and 0.2 to 2.0 weight. % Vanadium. The disclosure claims increase in pitting life only and does not address bending fatigue strength, essential for gear(s) and/or shaft of the components. Further the special steel used for processing requires special steel making process which increases production costs.

[0003] US-5,595,613 teaches to produce superior pitting resistance and wear resistance only with special steels having 1.5 to 5.0 weight .% Chromium .The treatment does not address bending fatigue strength. Further the special steel used for processing requires special steel making process which increases production costs.

[0004] Ups-5,019,182 claims to use heat treatment route which docs not address Tempering process. In absence of tempering process after quenching, quenching stresses are not relieved prior to service leading to dimensional instability and susceptibility to - cracking. Further, the bending fatigue strength is not addressed in the claim.

[0005] In light of the existing prior-art, there is long standing demand to provide both superior bending and pitting fatigue life on gear(s) and/or shaft components simultaneously using "conventional alloy steel " which is described as cheaper, most widely used and widely available steels for gear(s) and/or shaft components. All above disclosures do not provide complete solutions for producing both superior bending fatigue strength and pitting fatigue life simultaneously.

SUMMARY OF INVENTION

[0006] It is an object of the present invention to provide solutions to achieve both superior pitting and bending fatigue strengths of gear(s) and/or shaft components

[0007] According to the present invention, this object is performed by a method according to claim 1. This method allows the use of "conventional alloy steel" (hereafter called only "conventional steel") which is described as cheaper, most widely used and most widely available for gear(s) and/or shaft components. The method includes the following steps in sequence.

- Modified Carbonitriding treatment
- Hard Shot Peening process

[0008] The present invention allows to enhance the load carrying capability of transmissions without geometrical changes resulting in reduction of weights for higher load carrying capability, fuel consumption, development cost, development time and product cost and in turn give higher satisfaction to the customer.

[0009] The present invention allows to avoid geometrical changes in transmission components resulting in maintaining same weight and hence lower emission levels for enhanced load carrying capabilities.

[0010] The present invention allows to provide a solution to the problem of providing additional space in transmissions in case of geometric design changes are required to be introduced. The invention is also beneficial in such cases where the space constraints do not permit any geometric changes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The unique figure shows heat treatment cycle of Modified Carbonitriding. This is followed by Hard shot peening

DETAILED DESCRIPTION OF THE INVENTION

[0012] The present invention features achieving both superior bending fatigue strength and pitting fatigue life of gear (s) and / or shaft components using "conventional steel" by a method having following steps in sequence.

- Modified Carbonitriding treatment
- Hard Shot Peening process

[0013] "Conventional steel" used in the present invention is either one of the following types.

"Conventional steel" type 1 :

[0014] Steel material comprising 0.10 to 0.30 weight % Carbon, 0.15 to 0.35 weight % Silicon, 0.8 to 1.5 weight % Chromium , 0.6 to 1.5 weight % Manganese , 0.017 to 0.040 weight % Aluminium , and balance iron including impurities , produced in vacuum degassing and alike routes.

"Conventional steel" type 2 :

[0015] Steel material comprising 0.10 to 0.30 weight % Carbon , 0.15 to 0.35 weight % Silicon , 0.3 to 1.5 weight % Chromium , 0.30 to 2.0 weight % Nickel , 0.08 to 0.50 weight % Molybdenum , 0.6 to 1.5 weight % Manganese, 0.017 to 0.040 weight % Aluminium and balance iron including impurities , produced in vacuum degassing and alike routes ,

[0016] The rationale for choosing the "conventional steel" having the said compositions are as follows:

"Conventional steel" type 1:

[0017] Carbon inherently present in any steel is restricted in the range of 0.1 to 0.3 weight %. Lower than 0.1 weight % will not have sufficient core strength after the present processing. More than 0.3% will lead to core brittleness and reduced toughness. The response to heat treatment process will also be poor depending on higher Carbon contents.

[0018] Silicon is an essential element for de-oxidation of molten steel and hence minimum of 0.15 weight % is specified to ensure that de-oxidation is effectively taken care of. Higher than 0.35 weight % will entail more silicate inclusions affecting forgeability, machinability and reliability in service.

[0019] Chromium is easily available element for increasing hardenability. It is limited between 0.8 to 1.5 weight % to ensure adequate hardenability in the steels for gear(s) and / or shall components, in combination with Manganese. Higher than the limits will entail intergranular oxidation in the heat treated layers during carburising.

[0020] Manganese is yet another essential element effective in de-oxidation during melting and imparting hardenability. Not less than 0.6 weight % ensures de-oxidation and holds sulphur together. More than 1.5 weight % will lead to forgeability and machinability problems. It is easily available and cheaper element to increase the hardenability of the material for adequate core strengths and reasonable toughness Aluminium content in the range 0.017 to 0.040 weight % gives fully killed steel and does not contribute significantly in the nitride formation and stabilizing retained Austenite necessitating use of Modified Carbonitriding treatment for the purpose.

[0021] Trace elements like Nb , Ti , Zr , Cu and B are adjusted in such a way that the total contents are below 0.60 weight % . Nitrogen content is kept at 55 to 90 parts per million(ppm) and hydrogen is not more than than 2.5 ppm . Calcium and Sulphur are usually added in suitable quantities to improve morphology of inclusions to facilitate machinability.

[0022] The steel during melting is treated by standard Vacuum degassing cycle to maintain lower oxygen contents (Oxygen content in the product not more than 20 ppm) and hence limit size and distribution of inclusions to a degree that the component is fit for the applications already mentioned .

"Conventional steel" type 2:

[0023] Carbon inherently present in any steel is restricted in the range of 0.1 to 0.3 weight %. Lower than 0.1 weight % will not have sufficient core strength after the present processing. More than 0.3% will lead to core brittleness and reduced toughness. The response to heat treatment process will also be poor depending on higher Carbon contents.

[0024] Silicon is an essential element for de-oxidation of molten steel and hence minimum of 0.15 weight % is specified to ensure that dc-oxidition is effectively taken care of. Higher than 0.35 weight % will entail more silicate inclusions affecting forgeability, machinability and reliability in service.

[0025] Chromium is easily available element for increasing hardenability. It is limited between 0.3 to 1.5 weight % to ensure adequate hardenability in the steels for gear(s) and / or shaft components, in combination with Manganese , Nickel and Molybdenum, of suitable quantities mentioned above. Higher than the limits will entail intergranular oxidation in the heat treated layers during carburising.

[0026] Nickel is another essential element effective in ensuring hardenability and improve toughness , required in critical applications. The required quantity is to be not less than 0.3 weight % for ensuring the toughness and hardenability. The upper limit is set to 2 weight % arrived at based on the effect in combination with other elements mentioned above.

[0027] Molybdenum is yet another highly effective element in promoting hardenability of the surface and in the core portion. The lower limit is set to 0.08 weight % to be effective in promoting hardenability. The upper limit of 0.5 % is set in combination with other elements mentioned above.

[0028] Manganese is yet another essential element effective in imparting hardenability, de-oxidation during melting .Not less than 0.6 weight % ensures de-oxidation and holds sulphur together. More than 1.5 weight % will lead to forgeability

and machinability problems. It is also easily available and cheaper element to increase the hardenability of the material for adequate core strengths and reasonable toughness.

[0029] Aluminium content in the range 0.017 to 0.040 weight % gives fully killed steel and does not contribute significantly in the nitride formation and stabilizing retained Austenite necessitating use of Modified Carbonitriding treatment for the purpose.

[0030] Trace elements like Nb , Ti , Zr , Cu and B are adjusted in such a way that the total contents are below 0.60 weight % . Nitrogen content is kept at 55 to 90 parts per million(ppm) and hydrogen is not more than than 2.5 ppm . Calcium and Sulphur are usually added in suitable quantities to improve morphology of inclusions to facilitate machinability.

[0031] The steel during melting is treated by standard Vacuum degassing cycle to maintain lowcr oxygen contents (Oxygen content in the product not more than 20 ppm) and hence limit size and distribution of inclusions to a degree that the component is fit for the applications already mentioned.

Modified Carbonitriding :

[0032] The gear(s) and/or shaft components are manufactured as per conventional gear machining practice for highway, off-highway vehicle transmissions and similar industrial transmissions. The said components after machining are loaded in a standard sealed quench furnace having requisite facilities for automatic measurement and feedback mechanisms for carbon potential, temperature and time and facility for ammonia introduction is to be in place. Furnaces other than standard sealed quench furnaces having above requisite capabilities are also covered in the object of the invention.

[0033] The first step in the heat treatment cycle is Carburising (Refer FIGURE). The carburising is done at 915 degree Centigrade with equal boost and diffusion periods with Carbon potential (Cp) 1.0 and 0.8 respectively , using carrier gas and enricher gases. The temperature of not less than 900 degree Centigrade at which the carbon diffusion is more pronounced is covered in the invention. The effective case depth covered is in the range of 0.3 to 1.7 mm (cut off hardness 513 Hv). Effective case depths less than 0.3 mm do not provide adequate pitting resistance and more than 1.7 mm have deleterious effects on the fatigue properties for the applications covered in the scope of invention.

[0034] At the end of carburising cycle , the component is cooled inside the furnace to 850 degree Centigrade and ammonia is introduced with 15% of the whole furnace gas mixture (rest of the percent being carrier gas). The cycle is carried out for minimum 30 minutes. Temperature not less than 840 degree Centigrade and not more than 870 degree Centigrade is also covered as part of the invention to facilitate pronounced nitrogen diffusion upto a depth of 0.3 mm. Similarly ammonia not less than 15% and not more than 20% of the whole furnace gas mixture is covered for the "conventional steel" in which nitrogen absorbing elements and elements promoting diffusion of nitrogen are not in sufficient quantities.

[0035] To minimize distortions in the steel components, quenching in suitable medium at 120 to 150 degree Centigrade is maintained in the present invention. Depending on the criticality of the component, the quenching medium temperature of not less than 50 C is covered in the object of the invention.

[0036] Tempering temperature of 180 degree Centigrade is adopted for the purpose of relieving quenching stresses, without reduction in retained austenite produced after quenching, as above. The temperature not less than 160 degree Centigrade is covered to relieve quenching stresses.

[0037] Hardness after Modified Carbonitriding is maintained at not less than 74U Hv at a depth of 0.05 to 0.35 mm below the surface. The stresses responsible for pitting (called "Hertzian" stresses) are maximum at depth range mentioned here in the applications mentioned above. The hardness will get further enhanced during Hard shot peening and will provide adequate safety against pitting failures for the applications already covered.

[0038] The bending fatigue strength, which is a function of maximum residual compressive stress below the surface, is also enhanced by Hard shot peening.

Hard Shot Peening :

[0039] Further processing by Hard shot peening of the gear(s) and/or shaft components has simultaneous benefits of increasing the bending fatigue strength not less than 30% and pitting fatigue life by more than 3 times. The results have been confirmed in severe, rigorous and accelerated transmission endurance trials for life time, in comparison with conventional " carburising " component run with conventional monograde GL-4 gear oil , with oil temperature reaching upto 95 degree Centigrade. Similar results are covered with GL-4 or higher performance category multigrade oils with the present invention.

[0040] The improvement in bending fatigue strength results are further confirmed with Residual stress measurements using non- destructive Rigaku X-ray diffraction treatment upto a depth of 150 microns of actual component with conventional "Carburising " route and " Modified Carbonitriding with Hard Shot Peening " method using "conventional steel" . The maximum residual compressive stresses of 1500 Mpa and corresponding bending fatigue strength improvement of

30 to 80 % are covered in the present invention.

[0041] The roughness and finish of the component surface influences the lubrication condition during engagement of with the mating components. Keeping in mind that the gears need to be within the intended surface quality norms, the parameters are limited to as below,

shot size ranging from 0.5 to 0.8 mm,
shot hardness 610 to 800 Hv,
shot velocity 60 to 150 m/sec ,
part coverage 200 to 500 % Almen A arc height 0.6 to 0.9 mm.

Claims

1. A method for producing steel components such as gears and/or shafts, the steel material comprising inter alia Carbon, Silicon, Chromium, and Mangan, the method comprising the following steps in sequence:

- subjecting said steel components to a process of Carbonitriding Treatment;
- subjecting said steel components to a process of Hard Shot Peening;

wherein for the achievement of superior bending fatigue strength and pitting fatigue life of said steel components, the alloy steel used comprises
balance iron including impurities, produced in vacuum degassing and alike routes;

0.10	to	0.30	weight%		Carbon, and
0.15	to	0.35	weight%		Silicon, and
0.6	to	1.5	weight%		Manganese, and
0.017	to	0.040	weight%		Aluminium,
and	either				
	0.8	to	1.5	weight%	Chromium,
or	0.3	to	1.5	weight%	Chromium, and
	0.08	to	0.5	weight%	Molybdenum, and
	0.30	to	2,0	weight%	Nickel,

wherein the process of Carbon Treatment includes the following steps in sequence:

- Carburising at 900 to 1050 degree Centigrade,
- Cooling down to 840 to 870 degree Centigrade for Carbonitriding with 15 to 20% Ammonia,
- Quench in a medium at 120 to 150 degree Centigrade

Tempering at 160 to 180 degree Centigrade;
and

wherein said process of Hard Shoot Peening is performed under the following parameters:

- shot size ranging from 0.5 to 0.8 mm,
- shot hardness 610 to 800 HV,
- shot velocity 60 to 150 m/sec,
- part coverage 200 to 500%, and
- Almen A arc height 0.6 to 0.9 mm.

2. Method according to claim 1, wherein said steel material comprising:

0.10	to	0.30	weight%	Carbon,
0.15	to	0.35	weight%	Silicon,
0.8	to	1.5	weight%	Chromium,
0.6	to	1.5	weight %	Manganese,

(continued)

0.017	to	0.040	weight %	Aluminium, and

balance iron including impurities, produced in vacuum degassing and alike routes.

3. Method according to claim 1, wherein said steel material comprising:

0.10	to	0.30	weight%	Carbon,
0.15	to	0.35	weight%	Silicon,
0.3	to	1.5	weight%	Chromium,
0.30	to	2.0	weight%	Nickel,
0.08	to	0.50	weight%	Molybdenum,
0.6	to	1.5	weight%	Manganese,
0.017	to	0.040	weight%	Aluminium and

balance iron including impurities, produced in vacuum degassing and alike routes.

4. Method according to at least one of claims 1 to3, wherein the process of Modified Carbon Treatment includes the following steps in sequence:

Carburising at 900 to 1050 degree Centigrade,
Cooling down to 840 to 870 degree Centigrade for Carbonitriding with 15 to 20% Ammonia,
Quench in a medium at 120 to 150 degree Centigrade
Tempering at 160 to 180 degree Centigrade.

5. Method according to at least one of claims 1 to 4, wherein said process of Hard Shoot Peening is performed under the following parameters:

shot size ranging from 0.5 to 0.8 mm,
shot hardness 610 to 800 HV,
shot velocity 60 to 150 m/sec,
part coverage 200 to 500%, and
Almen A arc height 0.6 to 0.9 mm.

6. Gear component produced in accordance with the method according to at least one of claims 1 to 5.

7. Shaft component produced in accordance with the method according to at least one of claims 1 to 5.

Patentansprüche

1. Verfahren zur Herstellung von Stahlkomponenten wie etwa Getrieben und/oder Wellen, wobei das Stahlmaterial unter anderem Kohlenstoff, Silizium, Chrom und Mangan umfasst, wobei das Verfahren nacheinander die folgenden Schritte umfasst:

- Unterziehen der Stahlkomponenten einem Prozess der Carbonitrierungsbehandlung;
- Unterziehen der Stahlkomponenten einem Prozess des Hartkugelstrahlens (hard shot peening);

wobei der Legierungsstahl, um eine hervorragende Biegedauerfestigkeit und Dauerlochfraßfestigkeit der Stahlkomponenten zu erhalten,
Rest Eisen mit Verunreinigungen, hergestellt auf Vakuumentgasungs- und ähnlichen Wegen,

0,10	bis	0,30 Gew.-%	Kohlenstoff und
0,15	bis	0,35 Gew.-%	Silizium und
0,6	bis	1,5 Gew.-%	Mangan und

(fortgesetzt)

0,017	bis	0,040 Gew.-%	Aluminium

und entweder

0,8	bis	1,5 Gew.-%	Chrom

oder

0,3	bis	1,5 Gew.-%	Chrom und
0,08	bis	0,5 Gew.-%	Molybdän und
0,30	bis	2,0 Gew.-%	Nickel

umfasst,
wobei der Prozess der Kohlenstoffbehandlung nacheinander die folgenden Schritte beinhaltet:

- Aufkohlen bei 900 bis 1050 Grad Celsius, Abkühlen auf 840 bis 870 Grad Celsius zum Carbonitrieren mit 15 bis 20% Ammoniak,
- Abschrecken in einem Medium bei 120 bis 150 Grad Celsius

Tempern bei 160 bis 180 Grad Celsius
und
wobei der Prozess des Hartkugelstrahlens mit den folgenden Parametern durchgeführt wird:

Kugelgröße im Bereich von 0,5 bis 0,8 mm,
- Kugelhärte 610 bis 800 HV,
- Kugelgeschwindigkeit 60 bis 150 m/s,
- Teilüberdeckung 200 bis 500% und
- Almen-A-Sogenhöhe 0,6 bis 0,9 mm.

2. Verfahren nach Anspruch 1, wobei das Stahlmaterial

0,10	bis	0,30 Gew.-%	Kohlenstoff,
0,15	bis	0,35 Gew.-%	Silizium,
0,8	bis	1,5 Gew.-%	Chrom,
0,6	bis	1,5 Gew.-%	Mangan,
0,017	bis	0,040 Gew,-%	Aluminium

und
Rest Eisen mit Verunreinigungen, hergestellt auf Vakuumentgasungs- und ähnlichen Wegen, umfasst.

3. Verfahren nach Anspruch 1, wobei das Stahlmaterial

0,10	bis	0,30 Gew.-%	Kohlenstoff,
0,15	bis	0,35 Gew.-%	Silizium,
0,3	bis	1,5 Gew.-%	Chrom,
0,3	bis	2,0 Gew.-%	Nickel
0,08	bis	0,50 Gew.-%	Molybdän und
0,6	bis	1,5 Gew.-%	Mangan,
0,017	bis	0,C40 Gew.-%	Aluminium

und
Rest Eisen mit Verunreinigungen, hergestellt auf Vakuumentgasungs- und ähnlichen Wegen, umfasst.

4. Verfahren nach mindestens einem der Ansprüche 1 bis 3, wobei der Prozess der modifizierten Kohlenstoffbehandlung nacheinander die folgenden Schritte beinhaltet:

Aufkohlen bei 900 bis 1050 Grad Celsius,
Abkühlen auf 840 bis 870 Grad Celsius zum Carbonitrieren mit 15 bis 20% Ammoniak,
Abschrecken in einem Medium bei 120 bis 150 Grad Celsius
Tempern bei 160 bis 180 Grad Celsius.

5. Verfahren nach mindestens einem der Ansprüche 1 bis 4, wobei der Prozess des Hartkugelstrahlens mit den folgenden Parametern durchgeführt wird:

Kugelgröße im Bereich von 0,5 bis 0,8 mm,
Kugelhärte 610 bis 800 HV,
Kugelgeschwindigkeit 60 bis 150 m/s,
Teilüberdeckung 200 bis 500% und
Almen-A-Bogenhöhe 0,6 bis 0,9 mm.

6. Getriebekomponente, hergestellt nach dem Verfahren nach mindestens einem der Ansprüche 1 bis 5.

7. Wellenkomponente, hergestellt nach dem Verfahren nach mindestens einem der Ansprüche 1 bis 5.

Revendications

1. Procédé pour produire des composants en acier tels que des engrenages et/ou des arbres, le matériau d'acier comportant en outre du carbone, du silicium, du chrome, et du manganèse, le procédé comportant les étapes suivantes en succession :

- soumettre lesdits composants en acier à un processus de traitement de carbonitruration ;
- soumettre les composants en acier à un processus de grenaillage de précontrainte dur ;

dans lequel pour obtenir une résistance à la fatigue en flexion supérieure et une résistance durable à la piqûre de corrosion desdits composants en acier, l'acier d'alliage utilisé comporte
du fer de compensation, comprenant des impuretés, produit par dégazage sous vide et moyens semblables ;

0,10	à	0,30	pour cent en poids de carbone, et
0,15	à	0,35	pour cent en poids de silicium, et
0,6	à	1,5	pour cent en poids de manganèse, et
0,017	à	0,040	pour cent en poids d'aluminium,

et soit

0,8	à	1,5	pour cent en poids de chrome

ou

0,3	à	1,5	pour cent en poids de chrome, et
0,08	à	0,5	pour cent en poids de molybdène, et
0,30	à	2,0	pour cent en poids de nickel,

dans lequel le processus de traitement du carbone comprend les étapes suivantes en succession :

- Carburation à 900 à 1 050 degrés centigrade,
- refroidir à 840 à 870 degrés centigrade pour la carbonitruration avec 15 à 20 % d'ammonium,
- tremper dans un milieu à 120 à 150 degrés centigrade,
- aire revenir à 160 à 180 degrés centigrade ; et

dans lequel ledit processus de grenaillage de précontrainte dur est effectué d'après les paramètres suivants :

- Taille de la grenaille allant de 0,5 à 0,8 mm,
- Dureté de la grenaille de 610 à 800 de dureté Vickers,
- Vitesse de à grenaille de 60 à 150 m/seconde
- Couverture de la pièce de 200 à 500 %, et
- Hauteur de l'Arc Almen de 0,6 à 0,9 mm.

2. Procédé selon la revendication 1, dans lequel ledit matériau d'acier comporte :

0,10	à	0,30	pour cent en poids	de carbone,
0,15	à	0,35	pour cent en poids	de silicium,
0,8	à	1,5	pour cent en poids	de chrome,
0,6	à	1,5	pour cent en poids	de manganèse,
0,017	à	0,040	pour cent en poids	d'aluminium, et

fer de compensation, comprenant des impuretés, produit par dégazage sous vide et moyens semblables.

3. Procécé selon la revendication 1, dans lequel ledit matériau d'acier comporte :

0,10	à	0,30	pour cent en poids	carbone,
0,15	à	0,35	pour cent en poids	de silicium,
0,3	à	1,5	pour cent en poids	de chrome,
0,30	à	2,0	pour cent en poids	de nickel,
0,08	à	0,50	pour cent en poids	de molybdène,
0,6	à	1,5	pour cent en poids	de manganèse,
0,017	à	0,040	pour cent en poids	d'aluminium, et

fer de compensation, comprenant des impuretés, produit par dégazage sous vide et moyens semblables.

4. Procédé selon au moins une des revendications 1 à 3 dans lequel le processus de traitement au carbone modifié comprend les étapes suivantes en succession :

Carburation à 900 à 1 050 degrés centigrade,
Refroidissement à 840 à 870 degrés centigrade pour la carbonitruration avec 15 à 20 % d'ammonium,
Tremper dans un milieu à 120 à 150 degrés centigrade,
Faire venir à 160 à 180 degrés centigrade.

5. Procédé selon au moins une des revendications 1 à 4, dans lequel ledit processus de grenaillage de précontrainte dur est effectué d'après les paramètres suivants :

Taille de la grenaille allant de 0,5 à 0,8 mm,
Dureté de la grenaille 610 à 800 de dureté Vickers,
Vitesse de la grenaille de 60 à 150 m/seconde,
Couverture de la pièce de 200 à 500 %, et
Hauteur d'Arc Almen A de 0,6 à 0,9 mm.

6. Composant d'engrenage produit d'après le procédé selon au moins une des revendications 1 à 5.

7. Composant d'arbre produit d'après le procédé selon au moins une des revendications 1 à 5.

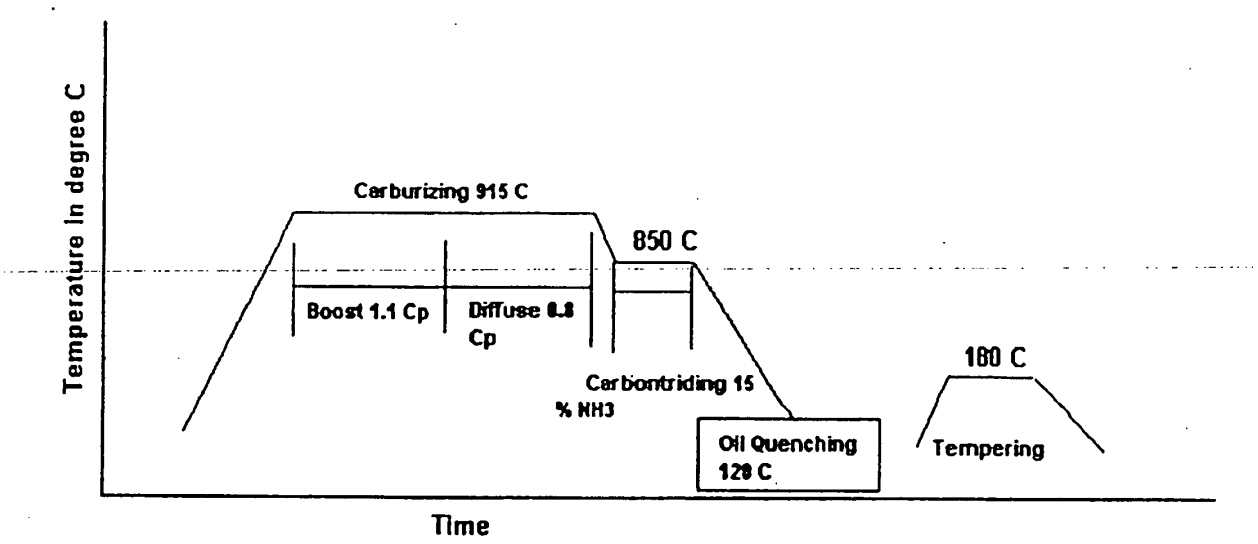

Temperature In degree C
Carburizing 915 C
850 C
Boost 1.1 Cp
Diffuse 0.8 Cp
Carbontriding 15 % NH3
Oil Quenching 120 C
180 C
Tempering
Time

FIGURE 1

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6447619 B **[0002]**
- US 5595613 A **[0003]**