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(54) **COMPACTING AND SINTERING STEEL POWDER**

PRESSEN UND SINTERN VON STAHLPULVER

COMPRESSION ET FRITTAGE DE POUDRE D'ACIER

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(73) Proprietor: **Instytut Obrobki Plastycznej**
Poznan (PL)

(72) Inventors:
- **WIŚNIEWSKA-WEINERT, Hanna;**
  PL-61-245 Poznan (PL)
- **SEWASTIANOW, Ewgienij, Stepanowicz;**
  Minsk (BY)
- **Leszczynski Wolf, Michajlowicz**
  Lugansk (UA)
- **STOJANOW, Aleksandr, Anatolewicz;**
  Lugansk (UA)
- **KUCZMA, Jurij, Jakowlewicz;**
  Lugansk (UA)

(74) Representative: **UEXKÜLL & STOLBERG**
Patentanwälte
Beselerstrasse 4
22607 Hamburg (DE)

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Description

[0001] The invention concerns a method of getting shaped elements by compaction, sintering and repressing of a steel powder mixtures with alloy additives, being used for production of machine parts, e.g. gears, bearings and others of high wear resistance and surface strength.

[0002] In well-known solutions, structural parts from powder mixtures with alloy additives are made by compaction and sintering at temperature 1100 - 1150 °C in a protective atmosphere. Products obtained by this method are characterized by high porosity up to 12% of volume and low compression strength.

[0003] In other method, a product from powder alloy steel is double pressed and double sintered at temperatures 800 °C and 1150 °C. In this solution, obtained products also do not get required high strength parameters.

[0004] There is also known a method of getting structural parts from steel powder mixtures with alloy additions, consisting in compaction, presintering at the temperature 800 - 850 °C, repressing of presintered semi-finished product and final sintering at the temperature 1120 - 1180 °C in a protective atmosphere. Parts obtained by this method have insufficient strength parameters, in particular low bending strength. A similar method is disclosed in EP-0 457 418 A1.

[0005] Moreover there is known a method of getting parts from metal powders with alloy additions, where compaction , presintering at temperature 650 °C, second pressing (repressing) and second sintering at temperature 1150 °C are carried out. Parts obtained by this method are characterized by low strength parameters, in particular low radial compression strength of ring products.

[0006] Presented above methods of getting products of steel powder mixtures with alloy additives do not precise pressure values that are to act onto shaped part, as well as they do not specify exact time during which sintering should be performed, giving a very wide temperature range.

[0007] Densification of powders during compaction in a closed die under pressure is performed as a result of mutual interparticle shear and plastic deformation of the powder particles. Their bonding at the definite stage of compaction arrests the interparticle shear process. So, further increasing of product density can take place only due to the deformation of powder particles. Intensive cold hardening of being pressed particles occurs. Further increasing compaction force is needed to deform a such powdered body and to overcome outside friction forces at the contact of powder material and a compaction tool. The result is to get high porosity after single compaction in the range from 15% to 20%.

[0008] Further increasing of product density can be obtained due to decreasing of metal flow stress and increasing of a compact plasticity, which may be achieved during presintering at temperatures equal to annealing temperature of a definite metal. So the process of presintering at annealing temperature makes possible to increase product density through its plastic deformation during repressing operation.

[0009] Plastic deformation of a presintered semi-final product, like for solid material, follows forming and shift of dislocations through crystal lattice at the definite slip planes. Plasticity and particularly densification ability of such sintered product, increase if, during first sintering, the elimination of structure elements (solid solutions, fine-grained particles, secondary phases, etc.) inhibiting dislocations' movement is achieved. That is why the first sintering should be conducted in conditions of recrystallization annealing at temperature A_{cl}.

[0010] The steel powder green compacts consist of a mixture of different components such as iron powder (or an alloyed iron powder) and graphite additives. The optimal presintering temperature of green compacts should in the range of 720 °C to 730 °C., A solubility of carbon in α-iron at this temperature range is about 0.03%, and the product after presintering is characterised by low yield strength and hardening coefficients as a result of lack of such strengthening factors as secondary phases, particle dispersability, etc.

[0011] It is well-known that diffusive mobility of iron atoms in carbon steels in state before transformation (for structural steels with alloyed elements of Cr, Mo, Ni, Cu) at 720 °C - 730 °C is approximately of the same value as in γ-iron at 1100 °C - 1200 °C.

[0012] During presintering diffusion processes of iron atoms in the range of temperatures 720 °C - 730 °C result in formation of interparticle bonding focuses (contact points).

[0013] The bonding contact points may be generally defined by positions of atoms belonging to both powder particles, separated with interparticle boundaries. An assembly of such contact points may be identified with "space contact lattice". The formation of interparticle interaction areas takes place not only as a result of "space contact lattice" motion along interparticle surfaces but also by verging of "space contact lattice" parameters towards matrix crystal lattice parameters. If a dissolving of carbon and alloy additions in iron at 720 °C - 730 °C does not take place, then parameters of "space contact lattice" can be changed in wide range by varying time of sintering at above temperatures.

[0014] After definite time of sintering, interparticle contact points make a system of glide planes, which is used as a system of glide planes inside grains and particles at ambient (room) temperature. Gliding along interparticle connections takes place under outside presssure, what has an essential importance to the process of plastic strain. Similar model can be called a model for "super dislocation" because it is based on an effective gliding along particle boundaries as a result of particular shift kind of "space contact lattice". This leads to additional, significant increase of sintered semi-final product palsticity, because it is known that metal material plasticity increases significantly if an additional mech-

anism of plastic strain, besides gliding at dislocation shift, is introduced into a process of plastic metal flow.

[0015] Taking into account above-mentioned conditions, a method being a subject of the invention has been developed.

[0016] The essence of the invention, concerning a method of getting shaped elements by pressing, sintering and compacting of powder mixtures of steel with alloy additions, consists in that a preformed element is treated with presintering, preferably in dissociated-ammonia atmosphere at temperature 700 - 750 °C, preferably 720 - 730 °C, during 20 - 40 min, preferably 30 min, and first compacting under pressure 700 - 800 MPa, preferably 750 MPa, and then second compacting with simultaneous calibration under pressure 900 - 1000 MPa, preferably 950 MPa, then final sintering at temperature 1100 - 1200 °C, preferably 1120 - 1150 °C, during 40 - 50 min, preferably 45 min.

[0017] Thanks to use of the method according to the invention, the following technical-and-operational effects were gained:

- high wear, crushing, shear and compressive strength of got product
- high yield point,
- density of got product above 7.6 g/cm^3,
- low material flow coefficient, in the range 10^{-2} - 10^{-3} mm,
- decrease of production power consumption,
- possible use for products of optional shapes, optional application, especially for products of required high strength as gears, bearings, etc.

[0018] Subject of the invention is shown in the following exemplary embodiments:

Example I

[0019] Preformed semi-final product from powder mixtures of steel with alloy additions of brass, nickel, copper, and others is treated with presintering in dissociated-ammonia atmosphere at temperature 725±5 °C during 30 min, and treated with compacting under pressure 750 MPa. Then it is treated with second compacting under pressure 950 MPa and calibration, then final sintering at temperature 1130 °C during 45 min.

Example II

[0020] Preformed semi-final product from powder mixtures of steel with alloy additions of brass, nickel, copper, and others is treated with presintering in dissociated-ammonia atmosphere at temperature 740±5 °C during 25 min, and first compacting under pressure 780 MPa. So prepared element is treated with second compacting under pressure 980 MPa and calibration, then final sintering at temperature 1180 °C during 40 min.

Example III

[0021] Preformed semi-final product from powder mixtures of steel with alloy additions of brass, nickel, copper, and others is treated with presintering in dissociated-ammonia atmosphere at temperature 710±5 °C during 35 min, and first compacting under pressure 710 MPa, then it is treated with second compacting under pressure 910 MPa and calibration, then final sintering at temperature 1100 °C during 50 min.

[0022] In the enclosed table, the results of strength tests of parts made from powder mixtures of steel with alloy additions, made with the method according to the invention at different temperatures of the first sintering compared with standard sample made with hitherto method.

No.	Powder chemical composition	Method of carrying out	Temperature of presintering °C	Bending strength of gear teeth ξ_i kG/mm^2	Coefficient ξ_i at 720°C *new* / *standard*
1.	0.55 – 0.62%C	Standard	650	200.0	
2.	3.8 – 4.2%Ni	New	715	360.0	
3.	1.8 – 2.2%Cu		720	370.0	
4.	0.3 – 0.5%Mo		725	370.0	1.85
5.			700	280.0	
6.			750	300.0	
7.			800	280.0	
8.	0.35 – 0.42%C	Standard	650	198.0	
9.	1.8 – 2.2%Ni	New	715	350.0	
10.	1.8 – 2.2%Cu		720	356.0	
11.	0.3 – 0.5%Mo		725	356.0	1.8
12.			700	270.0	
13.			750	300.0	
14.			800	275.0	
15.	0.55 – 0.62%C	Standard	650	178.0	
16.	0.8 – 1%Cr	New	715	268.0	
17.	1.8 – 2.2%Ni		720	286.0	
18.	0.3 – 0.8%Mn		725	286.0	1.6
19.			700	220.0	
20.			750	238.0	
21.			800	214.0	
22.	0.25 – 0.32%C	Standard	650	167.0	
23.	1.5 – 2.1%Ni	New	715	238.0	
24.	0.3 – 0.5%Mo		720	259.0	
25.			725	259.0	1.55
26.			700	222.0	
27.			750	235.0	
28.			800	230.0	

Claims

1. A method of getting shaped elements by sintering and pressing, of powder mixtures of steel with alloy additions, in which a preformed semi-final product is treated with presintering, and first compacting under pressure 700 - 800 MPa, and then second compacting with simultaneous calibration under pressure 900 - 1000 MPa, then treated with final sintering at temperature 1100 - 1200 °C,

2. A method according to claim 1, **characterized in that** the presintering treatment is carried out in dissociated-ammonia atmosphere at temperature 700 - 750 °C, preferably 720 - 730 °C.

3. A method according to claim 2, **characterized in that** the presintering treatment is carried out during 20-40 min, preferably 30 min.

4. A method according to any of the claims 1 to 3, **characterized in that** the first compacting pressure is 750 mPa.

5. A method according to any of the claims 1 to 4, **characterized in that** the second compacting pressure is 950 mPa.

6. A method according to any of the claims 1 to 5, **characterized in that** the final sintering temperature is 1120-1150°C.

7. A method according to any of the claims 1 to 6, **characterized in that** final sintering is carried out during 40 - 50 min, preferably 45 min.

Patentansprüche

1. Verfahren zum Herstellen von geformten Elementen durch Sintern und Pressen von Pulver-Mischungen, die Stahl und Legierungszusätze enthalten, bei dem ein vorgeformtes, halbfertiges Produkt durch Vorsintern und erstes Verdichten unter einem Druck von 700-800 MPa und dann durch ein zweites Verdichten mit gleichzeitiger Kalibrierung unter einem Druck von 900-1000 MPa bearbeitet wird, und dann durch Endsintern bei einer Temperatur von 1100-1200 °C bearbeitet wird.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Vorsinter-Bearbeitung in einer dissoziierten Ammoniak-Atmosphäre bei einer Temperatur von 700-750 °C, vorzugsweise 720-730 °C, durchgeführt wird.

3. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** die Vorsinter-Bearbeitung für 20-40 Minuten, vorzugsweise 30 Minuten, durchgeführt wird.

4. Verfahren nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** der erste Verdichtungsdruck 750 MPa beträgt.

5. Verfahren nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** der zweite Verdichtungsdruck 950 MPa beträgt.

6. Verfahren nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, dass** die Endsinter-Temperatur 1120-1150 °C beträgt.

7. Verfahren nach einem der Ansprüche 1 bis 6, **dadurch gekennzeichnet, dass** das Endsintern für 40-50 Minuten, vorzugsweise 45 Minuten, durchgeführt wird.

Revendications

1. Procédé permettant d'obtenir des éléments formés par frittage et compression de mélanges pulvérulents d'acier en ajoutant des alliages, dans lequel un produit semi-final préformé est traité en lui faisant subir un pré-frittage et un premier compactage à une pression comprise entre 700 et 800 Mpa, puis un second compactage avec un étalonnage simultané à une pression comprise entre 900 et 1 000 Mpa, puis un frittage final à une température comprise entre 1 100 et 1 200° C.

2. Procédé selon la revendication 1, **caractérisé en ce que** le traitement de pré-frittage est réalisé dans une atmosphère d'ammoniac dissocié à une température comprise entre 700 et 750° C, de préférence comprise entre 720 et 730° C.

3. Procédé selon la revendication 2, **caractérisé en ce que** le traitement de pré-frittage est réalisé pendant une durée comprise entre 20 et 40 mn, de préférence 30 mn.

4. Procédé selon l'une quelconque des revendications 1 à 3, **caractérisé en ce que** la première pression de compactage est 750 Mpa.

5. Procédé selon l'une quelconque des revendications 1 à 4, **caractérisé en ce que** la seconde pression de compactage est 950 Mpa.

6. Procédé selon l'une quelconque des revendications 1 à 5, **caractérisé en ce que** la température de frittage final est comprise entre 1 120 et 1 150° C.

7. Procédé selon l'une quelconque des revendications 1 à 6, **caractérisé en ce que** le frittage final est réalisé pendant une durée comprise entre 40 et 50 mn, de préférence 45 mn.