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(54) **Sinter-sizing of sintered steels**

(57) The present invention provides a simple and cost effective method for producing sintered components of varying size and compositions having through holes or holes wherein the through holes or holes have a high dimensional tolerance and in case of circular holes or through holes high roundness without the need for machining of the through holes or holes.

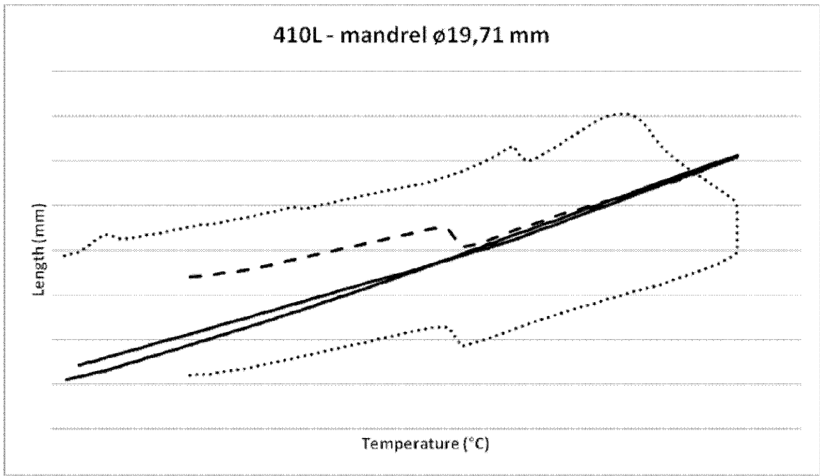

Figure 1

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Description

FIELD OF THE INVENTION

[0001] The present invention concerns a method of producing sintered components, and sintered components made by the method. The method provides a cost effective production of sintered steel parts with improved dimensional accuracy and control.

BACKGROUND OF THE INVENTION

[0002] In industries the use of metal products manufacturing by compaction and sintering metal powder compositions is becoming increasingly widespread. A number of different products of varying shape and thickness are being produced and the quality requirements are continuously raised at the same time as it is desired to reduce the cost. As net shape components, or near net shape components requiring a minimum of machining in order to reach finished shape, are obtained by press and sintering of iron based powder compositions in combination with a high degree of material utilisation, this technique has a great advantage over conventional techniques for forming metal parts such as moulding or machining from bar stock, casting or forgings.

[0003] It is desirable to increase the performance of sintered parts so that more parts can be substituted to this cost effective technique. Various industrial steel components, for instance in the automotive industry, have successfully been produced by the press and sintering technique. Automotive parts are manufactured in high volume for applications having strict performance, design and durability requirements. The single press and single sintering technique is therefore very suitable for production of such parts, provided that the overall quality requirements can be met.

[0004] A technical problem with the sintering process is that dimensional changes, such as shrinkage or swelling, are very common and affect the dimensional stability of the produced parts, and thus the tolerances achieved. These dimensional changes can also affect geometrical parameters such as roundness, if the dimensional change varies between different sections of the product. In order to overcome the problem with varying dimensional change between products in a production run and also within the products various kinds of machining operations may be necessary in order to reach an acceptable level of dimensional tolerance. Such additional machining operations will of course add manufacturing costs, especially when the sintered components are difficult to machine.

SUMMARY OF THE INVENTION

[0005] The present invention provides a simple and cost effective method for producing sintered components of varying size and compositions having through holes or holes wherein the through holes or holes have a high dimensional tolerance and in case of circular holes or through holes high roundness without the need for machining of the through holes or holes.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE LEGENDS

[0006] Figure 1 shows schematically the results from dilatometric measurements during the sintering cycle of a sample made from composition 2 without mandrel (dotted line) and with a mandrel having a diameter of 19.71 mm (dashed line). The dialtometric measurements of the mandrel are shown as well (full line). The phase transformation ferrite to austenite and austenite to ferrite is clearly indicated in the graph as abrupt change of inclination.

[0007] A metal powder composition is compacted or densified into a green component having at least one hole or through hole. Before sintering of the green component a mandrel is placed in the through hole or hole. The dimensions or diameter of the mandrel must be smaller than the dimensions or diameter of the hole allowing the mandrel to be inserted in the hole. The mandrel shall be made of a material which does not undergo any phase transformation during the sintering cycle and preferably having as constant coefficient of heat expansion or as close as possible constant coefficient of heat expansion with respect to temperature. Examples of suitable materials for the mandrel are austenitic stainless steel, ceramic materials or the like, austentic stainless steel is preferred. In case of a mandrel made of metal it is preferred that the thin metal oxide surface layer of mandrel contains stable oxides such as chromium oxides or aluminium oxides in order not to be subjected to any redox reaction during the sintering cycle preventing the mandrel to be thermal bonded to the component. A thin layer of an inert material such as fused silica or carbon black may also be applied on the envelope surface of the mandrel or of the component prior to sintering to prevent bonding. The dimensions or diameter of the mandrel is determined with respect to the swelling and shrinkage characteristics of the component to be sintered and shall be small enough to allow the mandrel to be inserted in the green body and to be removed without the need to apply such force that may destroy or causing distortion of the sintered body. The dimensions or diameter of the mandrel must also be big enough to causing the envelope surface of the mandrel to come into physical contact with the envelope surface of the hole of the component during the sintering cycle. The dimensional tolerance or roundness of the mandrel shall be chosen depending of the desired tolerance and roundness requirements of the hole of the sintered component. Thus the tolerance and roundness of the mandrel must be at least as high as the required tolerance and roundness of the hole. Furthermore the hot hardness of the mandrel must be high enough in order to withstand deformation. The green component with the inserted mandrel is heated during the sintering process up to the maximum sintering temperature, kept at the maximum sintering temperature for a predetermined time followed by cooling. During this cycle the mandrel will expand by the heat, the component will at the first part of the cycle expand by the heat but when sintering commence shrink and at a certain moment the envelope surface of the mandrel will meet the envelope surface of the hole thus applying a pressure on the envelope surface of the hole. During the subsequent cooling the mandrel and the component will shrink and at a certain temperature the physical contact between the envelope surface of the mandrel and the envelope surface of the hole will cease or the force acting on the envelope surface of the hole will be low enough allowing removal of the mandrel from the hole without causing any deformation of the sintered component. A prerequisite for the use of the method of the present invention is thus that the component will shrink during the sintering cycle to at least such degree that the dimensional change between green component and sintered component is at least 0.5%, preferably at least 1% and most preferably at least 2%. Examples of components which undergo such degree of shrinkage may be made from fine powders, i.e. powders having a median particle X_{50}, as measured according to SS-ISO13320-1, less than 20 μm. Other types of powders may be stainless steel powders having a martensitic or ferritic /martensitic microstructure or high speed steel such as M2 provided the sintering temperature is high enough and that the component exhibits a green density allowing such degree of shrinkage. The sintering temperature shall be at least 1000°C and up to 1400°C, preferably at least 1100°C and up to 1350°C

[0008] The method of the present invention hole is more beneficial for components which are difficult to machine, such components may contain hard phases such as carbides or nitrides. It is of special advantage to utilise the method of the present invention when producing components for turbo charger such as unison or nozzle rings or sliding nozzles.

[0009] In a special embodiment of the present invention the component is a made of a material which undergoes a reversible phase transformation from a phase with a more open structure to a phase having a denser structure, i.e. at a certain temperature shrinks during heating and at a certain temperature expands during cooling. An example of such material is the ferritic stainless steel powder 410L which will be transformed from ferrite to austenite during heating and back to ferrite during cooling.

[0010] Thus a method according to the present invention comprises the steps of;

a) providing a green component made of a densified powder having at least one hole and providing a mandrel having dimensions allowing the mandrel to be inserted in the hole of the green component, said mandrel and component having dimensions allowing the mandrel to exercise a pressure on the envelope surface of the hole during a period of time during the sintering process and having dimensions allowing the mandrel(s) to be removed from the component after sintering without causing deformation of the component,

b) inserting the mandrel(s) in the hole(s) of the component,

c) sintering the component with the inserted mandrel(s),

d) removing the mandrel(s) from hole(s) of the component.

[0011] The hole also includes a through hole.

[0012] A method for providing a suitable mandrel to be inserted in the hole of the green component may comprise the steps of;

a) Determining the desired hole diameter(s) or hole dimension(s) of the sintered component, and providing a press tool with core rod(s) suitable for compaction of the green component having a hole(s) or through hole(s) with dimension(s) which after sintering with a suitable mandrel to result in hole(s) or through hole(s) having dimensions as desired, and providing a suitable powder metallurgical composition,

b) compacting the composition in the press tool to a green component,

c) sintering the component and determining the dimensional change of the hole from green to sintered state,

d) providing a mandrel,

e) inserting the mandrel in the hole of the green component,

f) sintering the component with the inserted mandrel,

g) removing the mandrel from hole of the sintered component and evaluate the quality of the hole regarding tolerances and geometry,

h) optionally adjusting the dimensions of the mandrel

i) optionally repeating the process starting from e) until required tolerances and geometry are obtained.

j) if the quality of the hole(s) or through holes(s) is acceptable evaluate if the dimension(s) of the hole of the sintered component is acceptable,

k) optionally adjusting the dimension of the hole of the green component by adjusting size of the core rod and adjusting the size of the mandrel maintaining the same offset between core rod and mandrel.

EXAMPLES

Example 1

[0013] Three different powder metallurgical compositions were prepared by mixing different prealloyed metal powders with 0.8% of a lubricant, amidewax (ethylene bisstearamide). The properties, chemical composition and particle size distribution of the metal powders as according to table 1.

Table 1

Composition no	1 (20Cr13Ni)	2 (410L)	3 (M2)
% Cr	19.3	12.5	4.1
% Ni	13.3		
% Mo			4.9
% Mn	1.0	0.1	0.31
% W			6.2
% V			2.1
% Co			0.7
% Si	2.0	0.5	0.3
% C	0.5	0.02	0.81
% S	0.32		
% Fe	Balance Fe and inevitable impurities	Balance Fe and inevitable impurities	Balance Fe and inevitable impurities
Particle shape	Round agglomerates of fine atomised powder having mean particle size of about 10 μm	Irregular atomised powder	Irregular atomised powder
% +500 μm	0.5		
% 400-500 μm	7.5		
% 250-400 μm	42.3		
% 160-250 μm	31.9	0.1	0.7
% 100-160μm	13.8	BALANCE	BALANCE
% 45-100μm	2.5	BALANCE	BALANCE

(continued)

Composition no	1 (20Cr13Ni)	2 (410L)	3 (M2)
% -45μm	0.3	44	22

[0014] The powder compositions were compacted at a compaction pressure of 600 MPa for composition 1 and at 800 MPa for compositions 2 and 3 in uniaxial compaction movement into rings having nominal inner diameter of 20 mm, nominal outer diameter of 25 mm and a nominal height of 15 mm.

[0015] The actual diameters were here and further on measured with the aid of a three axial coordinate measuring device , Zeiss Calypso and the roundness were here and further on calculated according to below.

[0016] After compaction the roundness of the through hole was determined by measuring the difference between the biggest and the smallest diameter of the holes at five levels and the mean value of the differences was calculated and reported as roundness.

[0017] The rings were further subjected to sintering at 1250°C for rings made of composition 1, 1290°C for rings made of composition 2 and at 1270°C for rings made of composition 3 in an atmosphere of 90% nitrogen, 10% of hydrogen for a period of 30 minutes.

[0018] The roundness and the hole diameter, hereafter mentioned as nominal diameter, after sintering were thereafter determined.

[0019] Mandrels made of 316L steel and having various diameters were thereafter produced by machining of 316L steel rods. The diameters were equal to the nominal diameter, 0.15 mm greater than the nominal diameter and 0.15 less than the nominal diameter. The roundness of the mandrels was 0.01 mm or better.

[0020] The different mandrels were inserted in the green component rings respectively and sintered according to the procedure described above. After sintering the mandrels were removed and the "roundness" of the holes was measured. The results are summarized in the following table 2

Table 2

	Composition 1	Composition 2	Composition 3
Green component			
Average diameter of hole, [mm]	20 029	19 988	19 988
Roundness of hole[mm]	0 013	0 028	0 017
Component sintered without mandrel			
Average diameter of hole, [mm]	18 315	19 560	19 365
Roundness of hole[mm]	0 055	0 032	0 042
Dimensional change green-sintered %	8 56%	2 14%	3 12%
Sintered component with mandrel - 0 15 mm nominal diameter	Mandrel 18 17 mm	Mandrel 19 41 mm	Mandrel 19 22 mml
Roundness of hole[mm]	0 021	0 027	0 056 (to small diameter of mandrel)
Component sintered with nominal mandrel diameter	(Mandrel 18 32 mm)	(Mandrel 19 56 mm)	(Mandrel 19 37 mm)
Roundness of hole[mm]	0 061 (mandrel caused deformation)	0 021	0 016

(continued)

	Composition 1	Composition 2	Composition 3
Sintered component with mandrel + 0 15 mm nominal diameter	(Mandrel 18 47 mm)	(Mandrel 19 71 mm)	(Mandrel 19 52 mm)
Roundness of hole[mm]	N A Mandrel stuck in hole	0 018	0 016

[0021] As can be seen from table 2 the roundness can be improved with more than 50% by the method according to the present invention. For material 1 a mandrel having a diameter 0.15 mm less than the nominal diameter was suitable, and for materials 2 and 3 mandrels having a nominal diameter or 0.15 mm greater than the nominal diameter were suitable. Results are shown in figure 1.

[0022] Although the examples illustrates improvements in roundness of holes in a sintered component the scope of the present invention is not limited to improvements of roundness but also includes improvements of other geometrical errors caused during the sintering process.

Claims

1. A method for manufacturing a sintered component, having at least one hole, wherein the component shrinks during the sintering process, comprising the steps of;

a) providing a green component made of a densified powder having at least one hole and providing a mandrel having dimensions allowing the mandrel to be inserted in the hole of the green component, said mandrel and component having dimensions allowing the mandrel to exercise a pressure on the envelope surface of the hole during a period of time during the sintering process and having dimensions allowing the mandrel(s) to be removed from the component after sintering without causing deformation of the component,
b) inserting the mandrel(s) in the hole(s) of the component,
c) sintering the component with the inserted mandrel(s),
d) removing the mandrel(s) from hole(s) of the component.

2. A method according to claim 1 wherein the mandrel(s) is made of austenitic stainless steel or ceramic material.

3. A method according to any of claims 1-2 wherein the component shrinks at least 0.5%, preferably at least 1%, or most preferably at least 2% from green to sintered.

4. A method according to claim 3 wherein the powder is an austenitic stainless steel powder.

5. A method according to claim 4 wherein the powder has median particle size a particle size less than 20μm.

6. A method according to claim 3 wherein the powder is a high speed steel powder.

7. A method according to claim 3 wherein the powder is a ferritic or ferritic/martensitic stainless steel powder.

8. A component made from the method according to any of claims 1-7.

9. A component according to claim 8, said component being a turbo charger component.

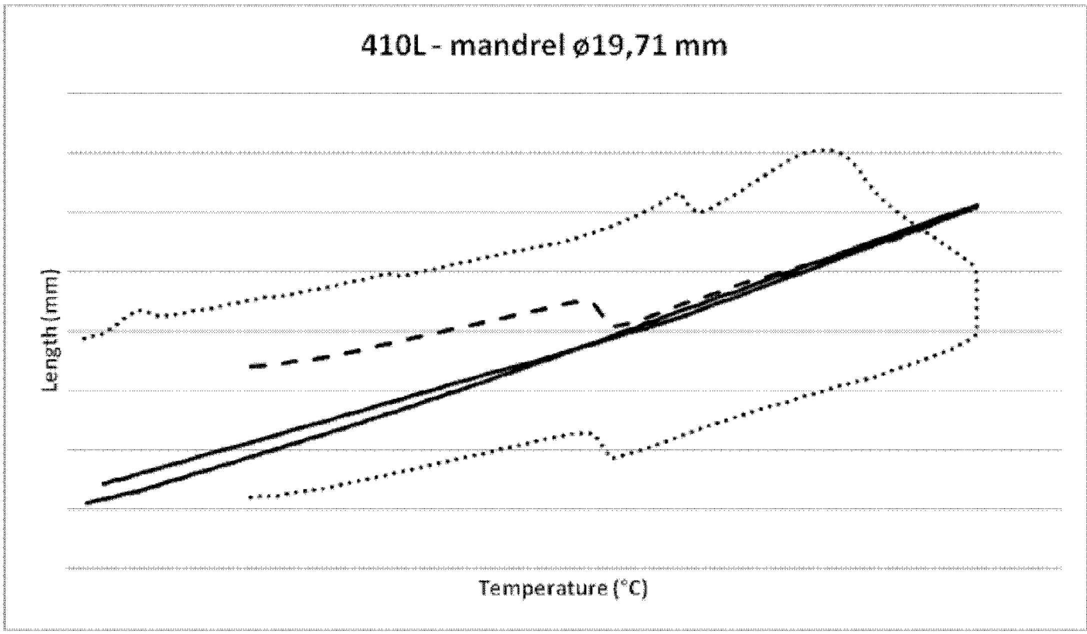

Figure 1

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EUROPEAN SEARCH REPORT

Application Number
EP 11 19 6061

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	US 3 992 202 A (DULIS EDWARD J ET AL) 16 November 1976 (1976-11-16) * claims 1-6; figures 1-3 *	1-9	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	4 July 2012	Liu, Yonghe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 19 6061

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