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(54) Title: APPARATUS AND METHOD FOR COMPACTING POWDER

(57) Abstract: The present invention relates to a method and an apparatus for compacting powder in a forming tool (100) that comprises a die (104), an upper punch (106) and a lower punch (108), for compacting during a pressing procedure of a powder material (109) to a compact. Respective position (N1, N2, N3) of each of the die (104), upper punch (106) and the lower punch (108), respectively, to said positions (N1, N2, N3) during the pressing procedure, is eligible by displacement of the die (104) and the respective punches (106, 108) relative each other, such that the relative positions (N1, N2, N3) for the die (104) and the respective punches (106, 108) in each separate position during a pressing procedure can be chosen. The present invention also relates to a forming tool.
Apparatus and method for compacting powder

Technical field

The present invention relates to a method and an apparatus for compacting powder.

Background

The present invention relates to the area of pressing powder material. In a pressing operation/process for compacting powder, several steps are carried out in a forming tool, such as inter alia powder-filling in a die, pressing from two opposite directions by punches towards the powder material in the die and subsequently uncovering of the compact, a so called green compact. According to applied methods today, the pressing process of compacted powder parts for forming of a green compact, during compacting powder in conventional forming tools, is carried out according to two traditional methods: the withdrawing method and the ejection method.

When the powder compacting should be carried out by the withdrawing method, a forming tool with a movable die, a movable upper punch and a stationary/fixed lower punch are used. According to the withdrawing method, the die is in its lower position and the upper punch is withdrawn to an initial position. Subsequently, the die is taken up to the filling position for powder filling, while the upper punch remains in its initial position, for filling of powder material in the recess of the die. Subsequently, the upper punch is brought flush with the upper surface of the die, whereupon pressing starts.

During the pressing, the upper punch is gradually brought in, bit by bit into the recess of the die, simultaneously as the die is moved down with half the velocity of the upper punch. Thus, the die is moved downwards during the
pressing towards its lower position, until the pressing of
the piece is fulfilled. After the pressing of the piece
has been completed, the die is run to its lower position,
such that the compact, i.e. the green compact, is brought
out of the recess in the die by the stationary lower
punch, at the same time as the compact is kept firm
between the upper punch and the lower punch. Then the
upper punch is returned completely to the initial
position, whereupon the pressed piece is uncovered.

When the powder compacting is carried out
according to the ejection method, a forming tool with
fixed/stationary die, movable upper punch and movable
lower punch is used. According to the ejection method, the
upper punch is withdrawn to its initial position, at a
distance from the die. The lower punch is in its initial
position, completely passed through the recess in the die,
such that its upper surface is flush with the upper
surface of the die. Subsequently, the lower punch is
brought down to the filling position for powder filling,
while the upper punch remains in its initial position, for
filling of powder material in the recess of the die.
Subsequently, the upper punch is brought flush with the
upper surface of the die, whereupon pressing starts.
During the pressing, the upper punch is gradually brought
in, bit by bit into the recess of the die, simultaneously
as the lower punch is moved up with the same velocity as
the upper punch is brought downwards, until the pressing
of the piece is fulfilled. According to the ejection
method, after the pressing of the piece is completed, the
lower punch is brought upwards to its upper position,
simultaneously as the upper punch is moved up
correspondingly as the lower punch. In that connection,
the pressed piece is pushed upwards out of the die
simultaneously as it is kept between the upper punch and
the lower punch. Then the pressed piece, i.e. the green compact, is finally uncovered by returning the upper punch completely to its initial position.

In course of time, heavier demands on the green compact have been put forward. On one hand, there is a demand to obtain high precision of the height of the green compact. On the other, there is a requirement to avoid cracking of the green compact. These two demands can be inconsistent by using the one and same method, the withdrawing method or the ejection method. With respect to the height of the green compact, the accuracy cannot always be sufficiently obtained with the withdrawing method. This is due to the fact that dimensional deviations arises when using a movable die. With respect to the ejection method, cracking for certain green compacts cannot be avoided to a sufficiently high extent. This depends on that power loading, power unloading and uncovering have to be done under supervised conditions.

WO-A1-2004/002659 relates to a method for compacting of a metal powder, in which method the compacting is done two times, with an intermediate movement of the compact in the die by performing a relative movement of the die and the lower punch, in comparison to each other. Finally, the compact is ejected from the die by the lower punch. The object with the method is to reduce the energy requirement for ejection of the compact from the die and to provide compacts having high green compact density.

**Description of the invention**

One object with the present invention is to achieve an apparatus and a method that at least partly eliminates those drawbacks that are associated with apparatuses according to the state of the art. One object
is further to increase the grade of accuracy of the height of the compact and simultaneously minimise cracking on the compact.

This object is achieved by a method for powder compacting in a forming tool according to the present invention as defined in claim 1. The forming tool comprises a die, an upper punch and a lower punch, for compacting during a pressing procedure of a powder material to a compact by mutually relative positioning of the die and the respective punches in at least an initial position, a powder filling position, a pressing position and a discharging position. The respective position of each of the die, the upper punch and the lower punch, respectively, to said positions during the pressing procedure, is eligible and varying by individual displacement of the die and the respective punches relative each other. In such a way, the relative positions for the die and the respective punches in each separate position during a pressing procedure can be chosen.

By the method, and the below disclosed forming tool, according to the present invention, an alternation between the withdrawing method and the ejection method is allowed before each new pressing procedure or even during the pressing procedure. Thus, in the one and the same forming tool it can be chosen, from compacting of a powder body to the next, if the withdrawing method or the ejection method should be applied, or a combination of the two methods during the pressing procedure. This implies that cracking can be minimised on the compact during power loading, unloading and when uncovering of the compact, for all kinds of compacts made of powder materials such as hard metals and ceramics. Thanks to a combination of withdrawing and ejection, the precision can be increased.
concerning the grade of accuracy of the height of the compact and dimensional deviations can be halved.

According to a preferred embodiment, the risk for tool collision is reduced, owing to that pressing is carried out by so called positive pressing tool, which means that the upper punch has a cross-section that is greater than the lower punch, whereby the upper punch will collide with the die if the upper punch is run to far down. The die has a conical part designed in the middle of the recess, between the upper side and the lower side of the die, which conical part has a decreased cross-sectional area in the direction against the lower side of the die and the lower punch. Mechanical stops can be provided at the forming tool. In that respect it is an advantage, when the die is moved to a mechanical stop, owing to that greater control of the position of the die in that connection is allowed, since it is desirable to come as close as possible to the conical part of the die, i.e. where the decrease in area begins in the recess of the die. This render a cost and time saving possible in the subsequent production stages, owing to that a subsequent grinding of the sintered products by the use of diamond grinding wheels to a large extent can be eliminated.

According to a preferred embodiment according to the present invention, is possible by the method, and the below disclosed forming tool, to perform a pressing of the powder material according to the ejection method, while uncovering of the compact can be provided by the withdrawing method.

The present invention relates also to a forming tool, according to the present invention as defined in the accompanying claims, for compacting powder. The forming tool comprising a die, an upper punch and a lower punch,
in which die the powder material is intended to be filled in a recess for forming of a solid compact by pressing of the punches towards the powder material in the die during a pressing procedure in at least an initial position, a powder filling position, a pressing position and a discharging position. The die and the respective punches are individually displaceable arranged relative each other to a respective eligible position during the pressing procedure.

The forming tool according to the present invention is preferably intended for static powder compacting.

Additional features and advantages according to embodiments of the invention, is evident from the claims and also in the following from description of the embodiments.

**Description of the drawings**

The present invention will now be described more in detail by examples of application, by reference to the accompanying drawings, without limiting the interpretation of the invention thereto, where

fig. 1 shows a part of an apparatus and method stages of the withdrawing method according to the state of the art,

fig. 2 shows a part of an apparatus and method stages of the ejection method according to the state of the art,

fig. 3 shows the forming tool according to an embodiment of the present invention, and

fig. 4 shows a part of the forming tool in fig. 3 and the method stages according to an embodiment of the present invention.
Detailed description of embodiments

A part of an apparatus and method stages of the withdrawing method according to the state of the art is shown in fig. 1. The apparatus, a so called forming tool 2, comprises a die 4, which is axially V movable arranged in the apparatus, an axially V movable upper punch 6 and a stationary, i.e. fixed, lower punch 8. The shown apparatus also comprises a so called core pin 10, that is axially V movable and centrally arranged and movable in a recess 12 in the die 4. The purpose of the core pin 10 is to make a hole in the compact, often in order to be fixed in a tool holder, cutter head or the similar. In the initial position, the core pin is positioned flush with the upper edge of the die. During pressing, the core pin is moved into the upper punch or is forced down by the upper punch. When using withdrawing or ejection, the core pin is pulled down when the compact is uncovered. In the initial position, according to the withdrawing method as evident from fig. 1, the die is in its lower position N1 and the upper punch 6 is withdrawn to its initial position N2 in the starting position A of the method. Subsequently, the die 4 is taken up to an upper position N3, the filling position B for powder filling, while the upper punch 6 remains in its initial position, for filling of powder material 13 in the recess 12 of the die 4. Subsequently, the upper punch 6 is brought flush with the upper surface 14 of the die 4 in the press starting position C, whereupon pressing starts. During the pressing, pressing position D, the upper punch 6 is gradually brought in, bit by bit into the recess 12 of the die, simultaneously as the die 4 is moved down with half the velocity of the upper punch 6. The purpose with this is that a so called "neutral zone" is desirable in the central parts of the green compact 13. During only unidirectional pressing by
one punch, from one side of the compact, the density will be highest on the side facing towards the pressing punch. This is often undesirable. Returning to the procedure of the method, the die 4 is thus moved downwards in direction down to its lowest position until the pressing of the piece, or green compact, is fulfilled. After the pressing of the green has been completed, the die 4 is run to its lower position N1, so called withdrawn position E, such that the green compact 13 is brought out of the recess 12 in the die while being supported by the stationary lower punch 8, at the same time as the compact is kept firm between the upper punch 6 and the lower punch 8. Then the upper punch 6 is returned completely to the initial position N2, collecting position F, whereupon the green compact 13 is uncovered.

A part of an apparatus and method stages of the ejection method according to the state of the art is shown in fig. 2. The apparatus, or the forming tool 50, comprises a fixed (stationary) die 54 arranged at a level N1, an axially V movable upper punch 56 and an axially V movable lower punch 58. Like the apparatus 2 in fig. 1, the forming tool 50 according to fig. 2 comprises an axially movable core pin 60, which is centrally arranged in the recess 62 of the die 54. With respect to the function and the arrangement of the core pin 60, reference is made to fig. 1 and the corresponding description to the figure. According to the ejection method, the upper punch 56 is withdrawn to its initial position N2 in the initial position A of the method, at a distance from the die 54. The lower punch 58 is in its initial position, completely passed through the recess 62 in the die, such that its upper surface is flush with the upper surface 64 of the die. Subsequently, the lower punch 58 is brought down to the filling position B for powder filling, while the upper
punch 56 remains in its initial position, for filling of powder material 65 in the recess 62 of the die.
Subsequently, the upper punch 56 is brought to level N1 flush with the upper surface 64 of the die in the starting position c, whereupon pressing starts. During the pressing, in pressing position d, the upper punch 56 is gradually brought in, bit by bit into the recess 62 of the die, simultaneously as the lower punch 58 is moved up with the same velocity as the upper punch 56 is brought downwards, until the pressing of the piece is fulfilled, in the same way as described according to the withdrawing method in fig. 1 above, in order to create a "neutral zone" in the central parts of the green compact 65.
According to the ejection method, after the pressing of the green compact is completed, the lower punch 58 is brought upwards to its upper position N1, ejected position e, simultaneously as the upper punch 56 is moved up correspondingly as the lower punch 58. In that connection, the pressed green compact 65 is pushed upwards out of the die 54, by simultaneous movement of the punches vertically upwards, simultaneously as the green compact is kept between the upper punch 56 and the lower punch 58. Then the pressed green compact 65 is finally uncovered by returning the upper punch 56 completely to its initial position N2, collecting position f.

A forming tool 100 for powder compacting, according to an embodiment of the present invention is shown in figs. 3 and 4. The forming tool comprises essentially a frame having an upper and a lower pressing cylinder and also a tool adaptor 102. The tool adaptor 102 comprises an axially V movable die 104, an axially V movable upper punch 106 and an axially V movable lower punch 108. The forming tool 100 also comprises a conventional core pin 110, which is axially V and
centrally arranged and movable in a recess 112 (see fig. 4) of the die 104. In the die is powder material 109 filled in the recess 112, by use of a powder feeding apparatus (not shown; see marked position for arrow P in fig. 3), for forming of a solid compact, a so called green compact, by pressing of the punches 106, 108 towards the powder material 109 in the die during a pressing procedure in at least an initial position A, a powder filling position B, a pressing position C, D and a discharging position E, F. The die and the respective punches are individually axially V displaceable arranged relative each other, suitably substantially in a vertical position, to a respective eligible position during the pressing procedure. The apparatus comprises a so called positive pressing tool, which more clearly is evident from fig. 4.

This implies that the upper punch 106 has a cross-section T1 that is larger than the cross-section T2 of the lower punch 108, whereby the upper punch 106 will collide with the die 104 if the upper punch is run too far downwards.

The die has a conical part 113 designed in the middle of the recess 112, between the upper side and the lower side of the die 104, which conical part has a decreased cross-sectional area in the direction towards the lower side of the die and the lower punch 108.

The forming tool 100 according to the present invention, as evident from fig. 3, comprises a first hydraulic cylinder 120 for axial V movement of the die 104, whose cylindrical block 122 is fixed to a first stationary supporting surface 124 at one side of the forming tool. The forming tool 100 further comprises a second hydraulic cylinder 130 for axial V movement of the upper punch 106, whose cylindrical block 132 is fixed to a second stationary supporting surface 134 at the other side of the forming tool. The forming tool 100 further
comprises a third hydraulic cylinder 140 for axial V movement of the lower punch 108, whose cylindric block 142 is arranged centrally of the forming tool. Further, forming tool 100 comprises a forth hydraulic cylinder 150 for axial V movement of the core pin 110, whose cylindric block 152 is arranged at the forming tool, closer to one end of the forming tool, in connection to the first hydraulic cylinder 120.

The forming tool 100 according to the present invention, as evident from fig. 3, further comprises a power sensor 160. The power sensor is used for registration of the power in shape of a curve as an aid in order to improve the pressing or to seek for reasons for cracking. It is used also as a tool protector, in order for example to cancel the pressing if the power becomes too high or low.

The positions of the hydraulic cylinders are controlled by position sensors enclosed in the tool adaptor 102. The position of the die in the filling position, which in the case with combined fixed and movable die also is the pressing position of the die, is decided by a fixed mechanical stop 170. The mechanical stop 170 is attached to the hydraulic cylinder 120 of the die 104, also called mechanical cylinder stroke limitation, in the left part in fig. 3. When the hydraulic cylinder 120 is run to this stop, the press alters function from a withdrawing press to an ejection press. Thus, the press according to the present invention, manages to alter between the different methods, withdrawing and ejection, during the one and the same pressing.

In fig. 4 is a part of the forming tool and the method stages shown, according to an embodiment of the present invention. The present invention relates to a
combination of the two, above mentioned, conventional methods, the withdrawing method and the ejection method. Thus, by the forming tool according to the present invention, it can be chosen if any of the two above described methods should be used, or if both methods in combination should be used during a pressing procedure. It can be provided, in accordance with the apparatus and method of the present invention, that the forming tool during the pressing procedure behaves like an ejection press and during the withdrawal (the uncovering of the solid powder body) behaves like a withdrawal press.

The forming tool comprises also a conventional controlling apparatus (not shown), suitably connected to a computer system that monitor, control and supervise various parameters such as pressing time, position sensors, etc.

Hereinafter follows examples of various pressing procedures, with reference to fig. 3 and 4, which can be obtained by the forming tool according to the present invention:

Example 1:

- The press/forming tool is in its initial position A:
  The die 104 is in its lower position N1, the upper punch 106 is in its upper position N2, and the lower punch 108 is in its lower position N1.
- The die 104 is moved up to its filling position B, level N3, which is decided by the fixed stop 170. The lower, first hydraulic cylinder 120 for movement of the die 104 keeps, during the time to the withdrawing phase, a higher force than that applied from the upper, second, hydraulic cylinder 130 for movement of the upper punch 106.
upper position N2, whereupon the green compact 109 can be removed from the pressing position (collecting position F).

5 The pressing described in example 1 thus starts with the ejection method (stationary die) and is finished with the withdrawal method (movable die). The huge advantage with this preferred method, according to an embodiment of the present invention, is that the die lies still against the mechanical stop when the upper punch travels down, in order to avoid tool collision, and that the withdrawal method can be used for uncovering of the green compact since only a work part is moving, i.e. the die. With the ejection according to the ejection method, both the upper punch and the lower punch have to be moved synchronous upwards.

For the purpose to make it clear, there should also be mentioned that the conventionally used core pin 110 usually is moved with pneumatic or hydraulic cylinder 150.

10 In the initial position A and during powder filling B, movement is carried out to flush with the upper edge of the die. During pressing C, D, it can remain in the same position (as shown in the drawings) or be carried along down with the upper punch. During uncovering of the compact, the core pin is pulled down.

Example 2
- The die 104 moves up to filling position B.
- Powder 109 is filled in.
- The upper punch 106 moves down into the die 104, which is kept still (to a start pressing position C).
- The lower punch 108 starts to move upwards in a coordinated movement with the upper punch 106 to a pressing position (pressing position D).
- Powder is filled in the die 104 to the correct volume by the aid of the powder filling apparatus of the press.

- In the start pressing position c, the upper, second, hydraulic cylinder 130 with the upper punch 106 travels towards the die surface 114.

- When the upper, second hydraulic cylinder 130 with the upper punch 106 has reached to a chosen position where the upper punch has reached into the die, the lower, third hydraulic cylinder 140 starts for movement of the lower punch 108 upwards, whereafter the both hydraulic cylinders, the second 130 and the third 140, coordinated moves towards each other to their respective pressing positions. The die is kept still during the pressing phase D against its mechanical stop 170.

- When the pressing positions of the second 130 and the third 140 cylinders have been reached, any chosen pressing time can be started if desired.

- When a set pressing time has been reached, or if no time has been chosen, the obtained pressing force for the upper, second hydraulic cylinder 130 and also for the lower, third hydraulic cylinder 140, is unloaded to a chosen resistance force that is maintained during the following withdrawal motion.

- When the pressing forces have been unloaded to set resistance force, the die starts its withdrawal movement downwards, withdrawn position E. The pressed green compact 109 is kept in its pressing position between the upper and lower punches 106, 108 during the withdrawal movement.

- When the die 104 has reached its lowest position N1, the upper, second hydraulic cylinder 130 with the upper punch 106 starts its movement upwards to its
- Both of the punches (106, 108) moves upwards synchronously and uncovers the green compact 109 (ejected position E; see fig. 2; and also collecting position F).

5

In the last mentioned stage in example 2, it is also possible that the die 104 can be brought down a little distance (withdrawn position E; see fig. 1) and remains in a standing position, and that the punches 106, 108 start to move upwards and uncovers the green compact 109. The arrangement and the function of the core pin is preferably as disclosed in connection to example 1 above.
Claims

1. A method for powder compacting in a forming tool (100) that comprises a die (104), an upper punch (106) and a lower punch (108), for compacting during a pressing procedure of a powder material (109) to a compact by mutually relative positioning (N1, N2, N3) of the die and the respective punches in at least an initial position (A), a powder filling position (B), a pressing position (C, D) and a discharging position (E, F), characterised in that the respective position (N1, N2, N3) of each of the die (104), the upper punch (106) and the lower punch (108), respectively, to said positions (N1, N2, N3) during the pressing procedure, is eligible and varying by individual displacement of the die (104) and the respective punches (106, 108) relative each other, such that the relative positions (N1, N2, N3) for the die (104) and the respective punches (106, 108) in each separate position during a pressing procedure can be chosen.

2. Method according to claim 1, characterised in that the die (106) and each of the punches (106, 108), respectively, in the discharge position (A) can be positioned such that an ejection procedure of the compact (109) can be performed, by displacement of the lower punch (108) upwards, or such that a withdrawal procedure of the compact (109) can be performed, by displacing the die (104) downwards, or a combination of said ejection procedure and withdrawal procedure.

3. Method according to claim 2, characterised in that pressing of the powder material in the pressing position (C, D) is performed according to the ejection procedure while uncovering (F) of the compact (109) is carried out by the withdrawal procedure.
4. Method according to any of the preceding claims, characterised in that the position of the die (104) in the filling position (A) and the pressing position (C, D) is decided by a mechanical stop (170), such that when a first hydraulic cylinder (120) for movement of the die (104) is run against this stop (170), the function of the forming tool (100) is altered from a withdrawal press to an ejection press.

5. A forming tool (100) for compacting powder, comprising a die (104), an upper punch (106) and a lower punch (108), in which die powder material (109) is intended to be filled in a recess (112) for forming of a solid compact by pressing of the punches towards the powder material in the die during a pressing procedure in at least an initial position (A), a powder filling position (B), a pressing position (C, D) and a discharging position (E, F), characterised in that die (104) and the respective punches (106, 108) are individually displaceable arranged relative each other to a respective eligible position (N1, N2, N3) during the pressing procedure.

6. Forming tool according to claim 5, characterised in that the die (104) is movable by aid of a first hydraulic cylinder (120) arranged at the forming tool (100) and that the lower punch (108) is movable by a third hydraulic cylinder (140) arranged at the forming tool (100).

7. Forming tool according to claim 6, characterised in that the upper punch (106) is movable by a second hydraulic cylinder (130) arranged at the forming tool (100).
8. Forming tool according to claim 6 or 7, characterised in that the positions of the hydraulic cylinders (120, 130, 140) are controlled by enclosed position sensors in the forming tool (100).

9. Forming tool according to any of the claims 5-9, characterised in that a mechanical stop (170) is arranged to the hydraulic cylinder (120) of the die (104).

10. Forming tool according to any of the claims 5-9, characterised in that it is intended for static powder compacting.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B30B, B22F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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Cited literature, if any, will be enclosed in paper form.
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